FRANKFORD ARSENAL

REPORT NO. R-1347

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EVALUATION OF CANOPY JETTISON SYSTEM PROPOSED FOR USE IN B-57B AIRPLANE

BY

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PROJECT TS1-15

PITMAN-DUNN LABORATORIES GROUP
FRANKFORD ARSENAL
Philadelphia, Pa.

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REPORT R-1347

EVALUATION OF CANOPY JETTISON SYSTEM PROPOSED FOR USE IN B-57B AIRPLANE

Project TS1-15

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OBJECT

To evaluate ballistically the proposed canopy jettison system for the B-57B airplane.

SUMMARY

The canopy jettison system for the B-57B aircraft has been evaluated by ballistic tests. The system consists of an M5 thruster for release of the canopy latches, an M3 remover for jettison of the canopy, and initiators with pressure transmission systems for actuation of these devices.

Tests were conducted to obtain data on the following:

(1) Study of the performance of the M3 remover propelling various mass loads;

(2) Study of the performance of the M5 thruster operated against a combined force and mass load approximating service conditions;

(3) Study of the function of the firing mechanism of the M3 remover with remover in tension and actuated by an M3 initiator through flexible hose; and

(4) Evaluation of performance of initiating systems which form parts of complete canopy jettison system.

The results of these tests have indicated that the canopy jettison system as proposed is satisfactory as far as ballistics are concerned.

AUTHORIZATION

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INTRODUCTION

In conjunction with the development of the B-57B aircraft, Glenn L. Martin Company, with the assistance of the Pitman-Dunn Laboratories Group of Frankford Arsenal, formulated plans for a combined ballistic and mechanical system to be used in emergency escape from this aircraft. Because of the time limitations no attempt was made to develop new ballistic devices. Complete reliance was placed on the available standardized cartridge actuated devices.

Emergency escape from this aircraft is accomplished in three phases: canopy jettison, control column stowage, and personnel ejection. The control column stowage and personnel ejection operations are initiated as a result of successful canopy jettison. The system is designed to insure proper sequence of operation.

In this project Frankford Arsenal undertook to investigate the ballistic performance of the system proposed for use in the emergency canopy jettison operation. For convenience the project was divided into five phases, each phase being concerned with a specific area of investigation. Performance requirements for system components were established after investigation of the various aspects of the canopy jettison operation. Test conditions were established to reflect the most stringent requirements service conditions can make on the performance of the system. In this report each phase is treated separately.

DESCRIPTION OF SYSTEM

Canopy Jettison System

The complete canopy jettison system is a complex assembly of ballistic and mechanical systems. In emergency escape it performs two functions: release of the canopy latches and jettison of the canopy. The equipment associated with emergency canopy jettison may be considered in two main categories: (1) equipment which is part of the service structure of the aircraft (canopy, canopy latches, hydraulic ram, etc.), and (2) ballistic systems (cartridge actuated devices and the ballistic assemblies used in device initiation).

A functional diagram of the canopy jettison system is shown in Figure 1. In this diagram the relative position occupied by each system component and its designation are shown. The diagram does not represent the actual spatial configuration the system assumes in the aircraft.

In the emergency escape operation, canopy jettison is effected by operation of the M3 remover. The remover is mounted in tandem with an hydraulic actuating cylinder and is attached to the canopy. The canopy is hinged at one end; for successful jettison it must be rotated through an angular displacement about the hinge. A schematic diagram showing the geometry of the canopy and mechanical data is shown in Figure 2.

The canopy latches in the B-57B aircraft are interconnected and are operated from one power source. In emergency canopy unlock the M5 thruster provides the power for this operation. The latch system is not massive but does provide considerable resistance to movement. Load vs stroke curves (Figure 3) show the opposing load provided by the latch systems for the following latch settings: aft, nominal, and forward. The resistive load declines rapidly with travel. Three inches of power stroke are required to complete canopy unlock.

The M5 thruster provides one other function. After canopy unlock has been effected, the continuing motion of the thruster piston is used to operate the M3 initiator which operates the M3 remover. A spring coupling joins the thruster piston and the initiator pin; thus proper sequence of the operations of canopy unlock and canopy jettison is assured.

The canopy jettison operation may be initiated from any one of three positions: navigator's seat, pilot's seat, and outside (for ground rescue). Function of the canopy jettison system commences with operation of any one of the three initiators mechanically fired at one of these positions. Propellent gas from the initiator is transmitted through an assembly of flexible hose (AN6271-4) and various fittings (type AN, size 4) and operates the firing mechanism of the M5 thruster. The transmission lines used in the initiation of the M5 thruster are maintained as independent channels by the use of check valves at the juncture of the three lines. This prevents gas from flowing into the unfired initiators, which would result in large pressure losses. Quick disconnects are included in the transmission lines for the initiators at the pilot's position and navigator's position, for convenient deactivation of the system without complete disassembly. After canopy unlock the second M3 initiator is fired and propellent gas from this initiator travels through a transmission line consisting of flexible hose (AN6271-4)

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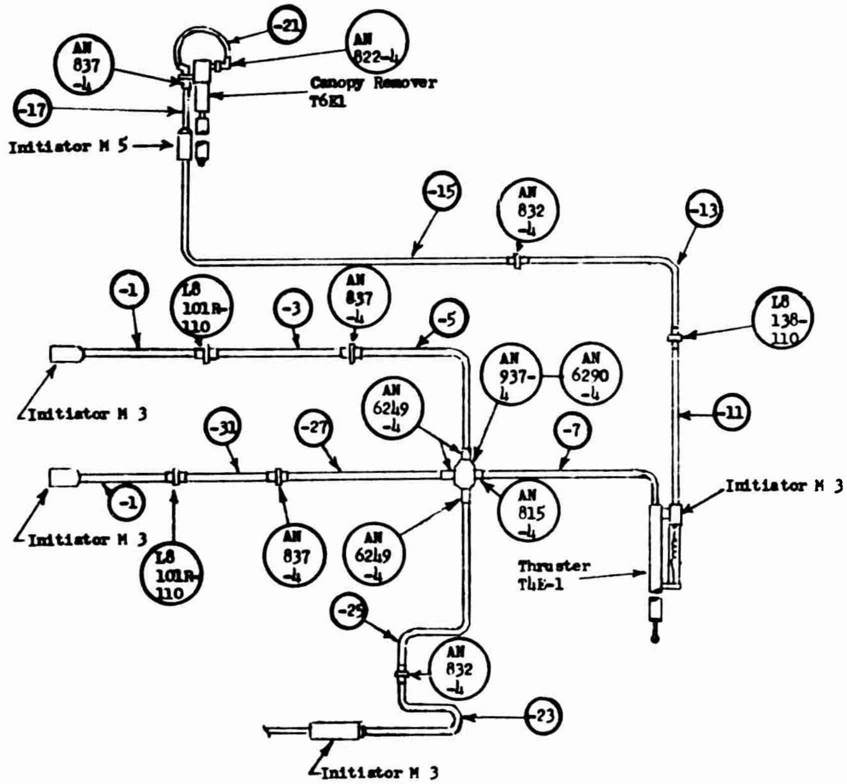

QUAN	SYMBOL	PART NAME	VENDOR'S DESIGNATION
2	L8-101R-110	Disconnect	(Wiggins) GLM E-115060
1	AN937-4	Cross	
4	AN6290-4	"O" Ring	
1	L8-133-110	Disconnect	(Wiggins) GLM E-115058
3	AN6249-4	Check Valve	
2	AN837-4	Elbow-45°	
2	AN832-4	Union Bulkh'd.	
1	AN815-4	Union	
1	AN822-4	Elbow 90°	
1	-31	Flex. -Hose	MS28741-4-380
1	-27	Flex. -Hose	MS28741-4-270
1	-25	Flex. -Hose	MS28741-4-500
1	-23	Tubing	272B6081001-9
1	-21	Flex. -Hose	MS28741-4-160
1	-17	Flex. -Hose	MS28741-4-122
1	-15	Flex. -Hose	MS28741-4-730
1	-13	Flex. -Hose	MS28741-4-114
1	-11	Flex. -Hose	MS28741-4-260
1	-7	Flex. -Hose	MS28741-4-120
1	-5	Flex. -Hose	MS28741-4-140
1	-3	Flex. -Hose	MS28741-4-720
2	-1	Flex. -Hose	MS28741-4-100

Figure 1. Functional diagram of canopy ejection system for B-57B aircraft.

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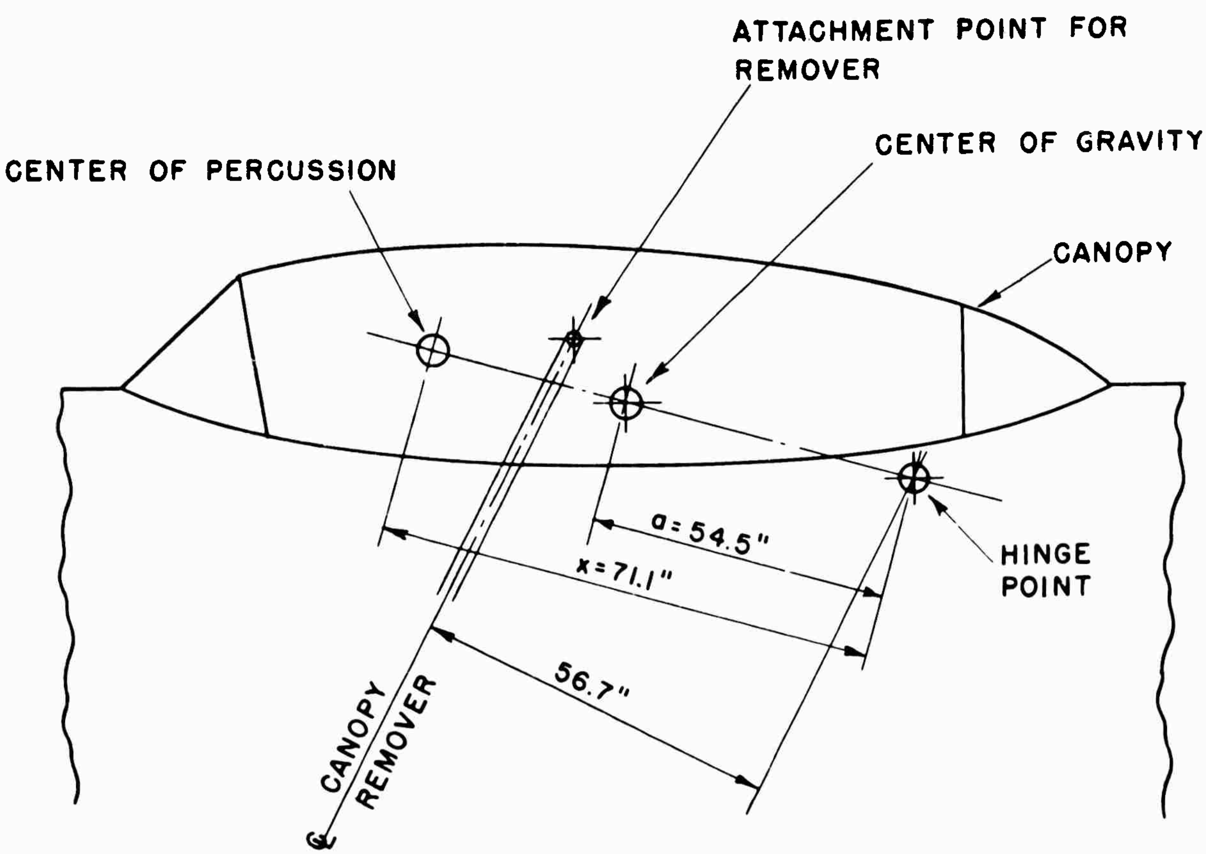

WEIGHT OF CANOPY = 301 LBS

MOMENT OF INERTIA ABOUT HINGE = 252 SLUG-FT^2

Figure 2. Schematic diagram, B-57B aircraft canopy geometry and mechanical data

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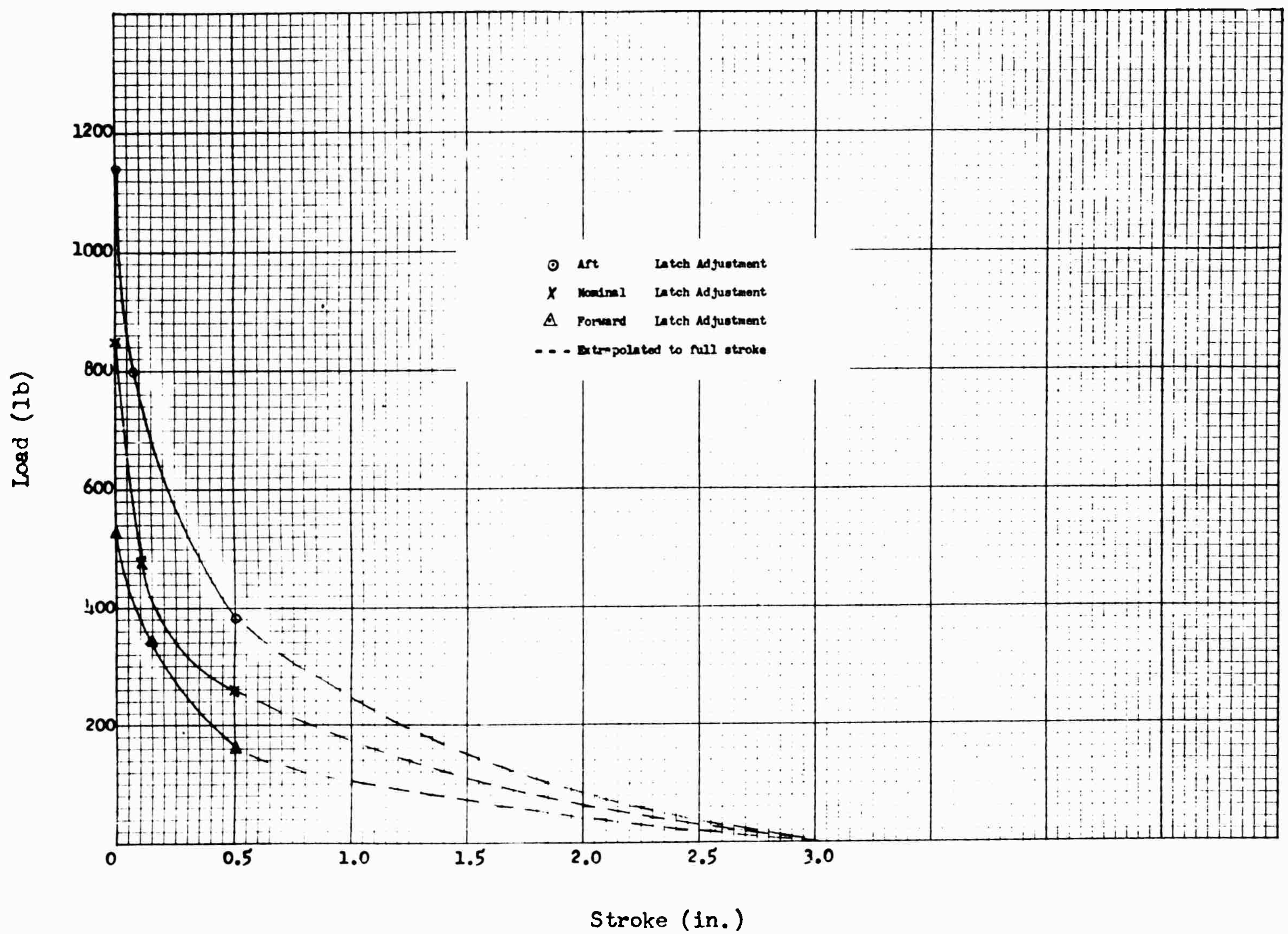

Figure 3. Load vs stroke curves for canopy latch, B-57B aircraft

and various fittings (type AN, size 4), and operates the booster initiator (M5 initiator). A quick disconnect* is also provided for this transmission line. Propellent gas from the booster initiator then operates the M3 remover, which jettisons the canopy.

The selection of components and the configuration of the system was largely dictated by the layout of the cockpit. The assembly distances between the remover, the thruster, and their initiators are as short as is practicable without sacrifice of compatibility of system configuration with other aircraft equipment and operational reliability of the canopy jettison system.

Cartridge Actuated Devices of System

Initiator, M3

The M3 initiator (Figures 4 and 5) is a device which generates propellent gas for the initiation of gas-operated cartridge actuated devices. This device is mechanically operated by withdrawal of the initiator pin. This is accomplished with a force of between 20 and 35 lb through a distance of 5/8 in. As Figure 5 shows, the initiator pin is surrounded by a coil spring and is joined to the firing pin by steel release balls which are seated partly in the locking groove of the initiator pin and partly in holes in the firing pin. When the initiator pin is withdrawn into the rear portion of the firing pin housing, which has a larger diameter than the forward portion, the balls are released, separating the firing pin from the initiator pin. The forward motion of the firing pin is arrested by the forward end of the firing pin housing to prevent excessive pin protrusion, which could cause primer cup puncture.

The initiator is assembled with the end of the cartridge retainer flush with the chamber wall. The face of the cartridge retainer is provided with four diametral grooves which, together with the chamber wall, form eight gas-metering orifices. The rate of gas flow, an important factor in ballistic performance of the initiator, is regulated by these orifices. The envelope drawing and assembled view of the M3 initiator are shown in Figure 4. The assembly drawing (sectional view) and exploded view are shown in Figure 5. Curves showing performance in simple ballistic systems

*For further details concerning the quick disconnects, see Reference 12.

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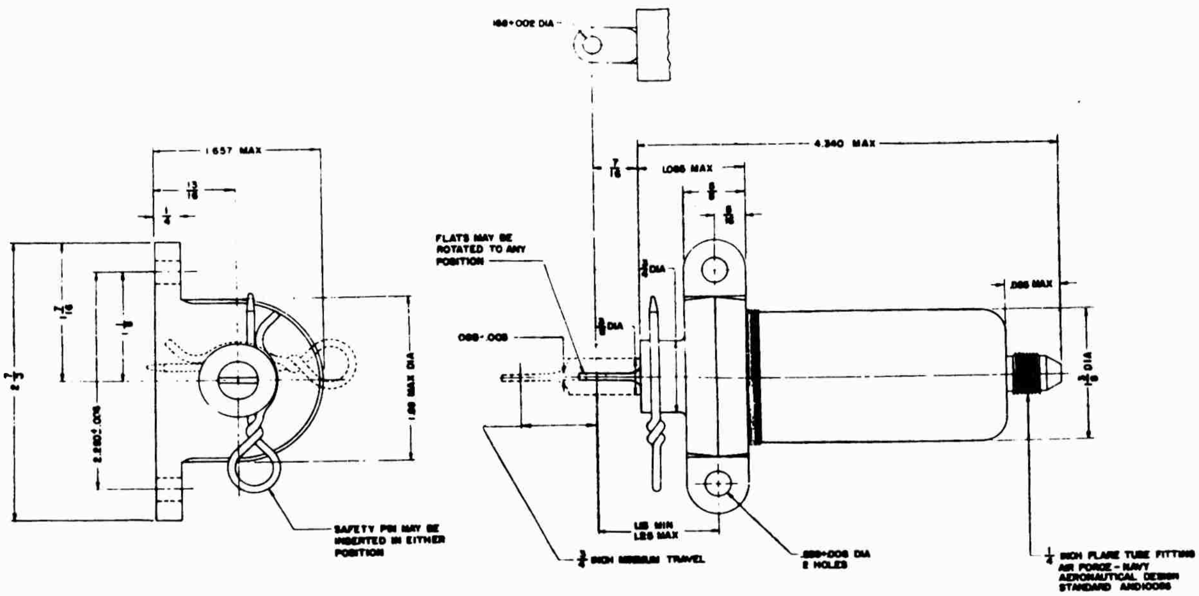

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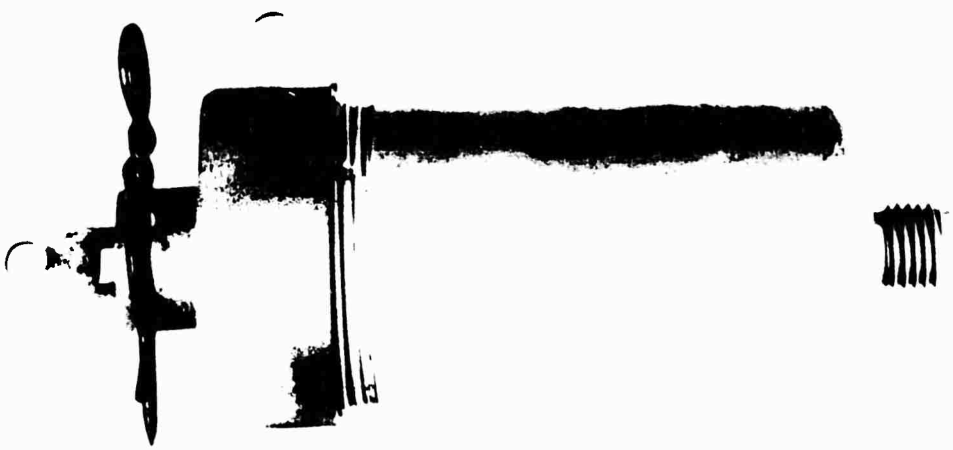

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Figure 4. M3 initiator

A - Envelope drawing
B - Assembled view

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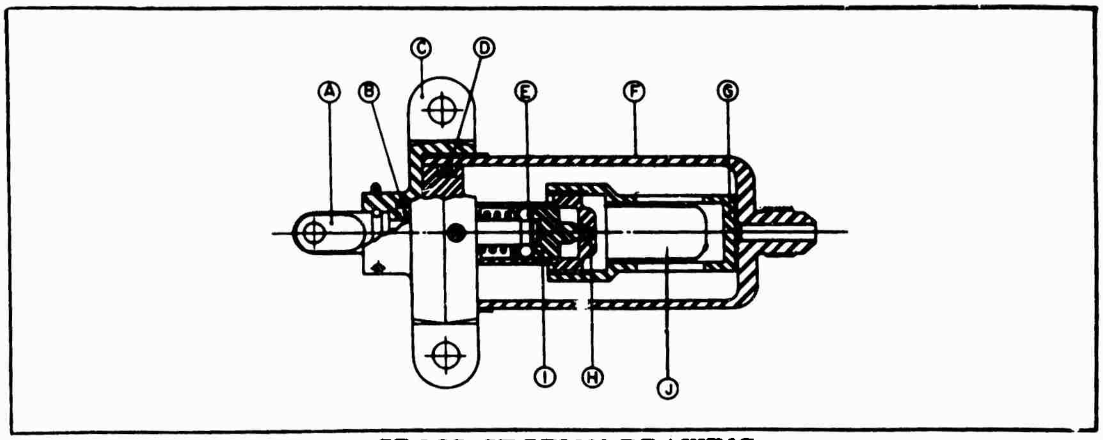
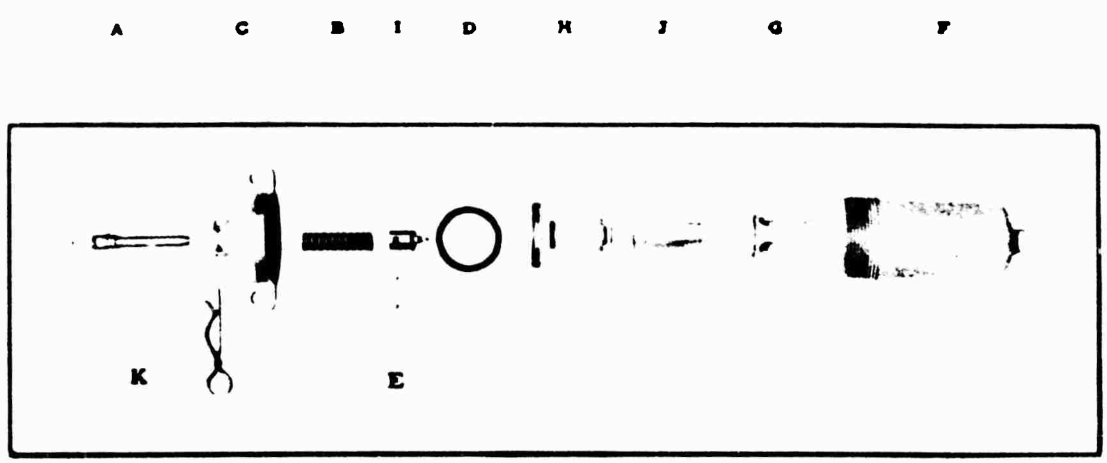


CROSS-SECTION DRAWING

	Component	Development Drawing Number	Ordnance Drawing Number
A	Pin Initiator	ALX-92-12	94-3-4A
B	Spring, Initiator	ALX-92-14	94-3-4B
C	Cap	BLX-92-11	94-3-4C
D	"O" Ring	AN6227-B19	CKCZ2587929
E	Ball, Metal	AN216C1-8	CCA43587929
F	Chamber	ALX-32-6	C8593014
G	Retainer, Cartridge	ALX-32-7	C8593013
H	Housing, Firing Pin	ALX-32-8	94-3-3A
I	Pin, Firing	ALX-32-10	94-3-3B
J	Cartridge, CAD, M38	BLX-34-1	95-1-15A
K	Pin, Safety	ALX-92-15	94-3-4D
	Assembly Drawing	BLX-32-1	94-3-2A
	Parts List		



EXPLODED VIEW

Figure 5. Cross-section drawing and exploded view, M3 initiator

consisting of the M3 initiator, flexible hose, and a chamber (volumes: 0.062 and 0.588 in.^{3}) are shown in Figure 6. Peak chamber pressure is plotted against length of flexible hose in the system. Engineering data concerning the M3 initiator follow.

Bursting pressure	12,100 psi
Volume (cartridge open)	2.3 in.^{3}
Assembled weight	0.9 lb
Force required to pull initiator pin	20 to 35 lb

Initiator, M5

The M5 initiator (Figure 7) was developed by the modification of the M3 initiator. The major difference between these devices is the method of operation. Several components (chamber, cartridge, retainer, etc) of both devices are identical. The M5 initiator is operated by the action of propellent gas on the firing pin, which is held in place by a shear pin. When sufficient pressure is developed, the firing pin is released.

The envelope drawing and assembled view of the M5 initiator are shown in Figure 7. The assembly drawing (sectional view) and exploded view are shown in Figure 8. Performance curves are shown in Figure 6. Engineering data concerning the M3 initiator apply also to the M5 initiator except for the method of firing.

This device is used in escape systems as a booster. In the design of an escape system it is often necessary to maintain an assembly distance between the cartridge actuated device and its initiator, which is too long for reliable initiation with a single initiator. In such circumstances an M5 initiator may be included in the transmission line at an appropriate place. The device is also used with by-pass type thrusters and similar by-pass devices.

Thruster, M5

Certain operations connected with emergency escape from high speed aircraft, such as canopy unlock, canopy or tail turret jettison, and other such operations, frequently require the application of large forces over a short period of time (of the order of 0.01 to 0.08 sec).

One device frequently used in such applications is the M5 thruster. This device is capable of delivering large amounts of power and occupies little space in installation (assembly length, 12.1 in. and power stroke, 5 in.).

The thruster consists essentially of a firing head assembly, body, piston, and M38 cartridge. Thrust is developed by the action of

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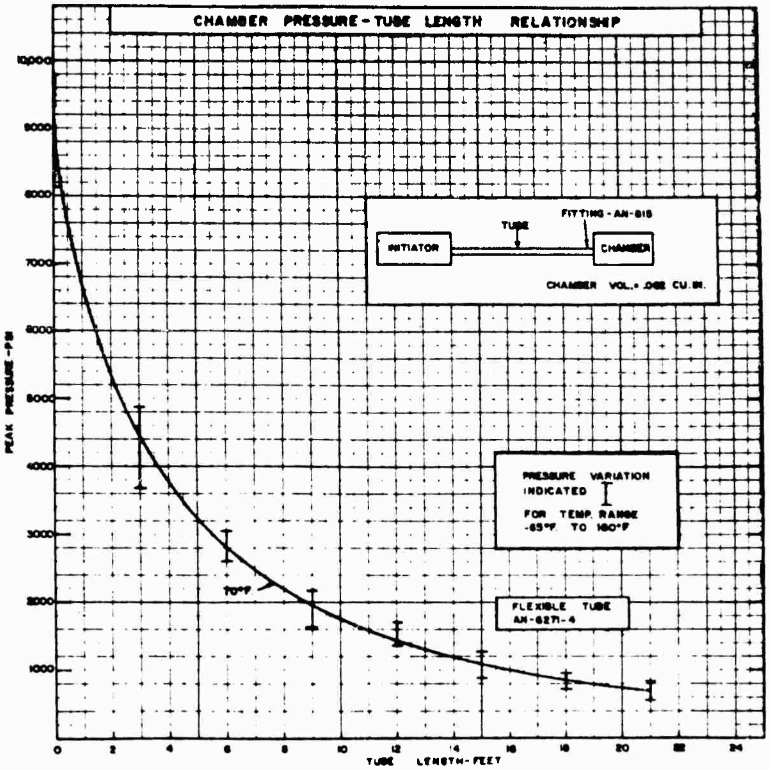

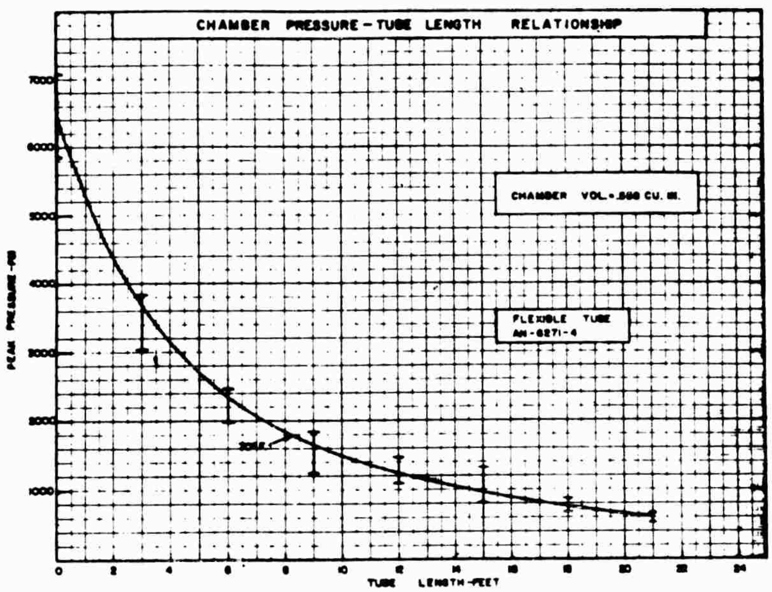

Figure 6. Performance curves, M3 and M5 initiators

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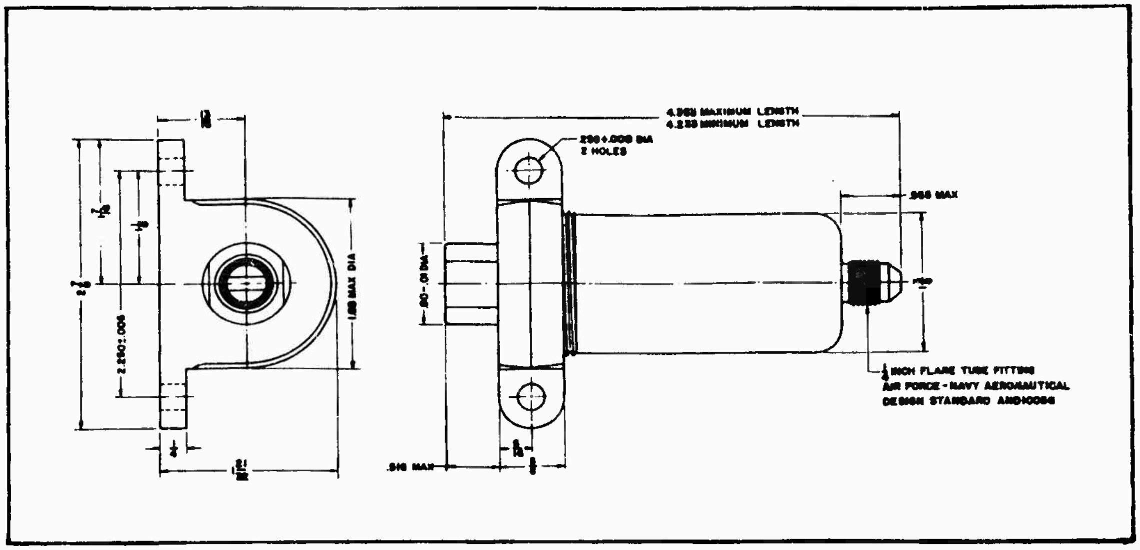

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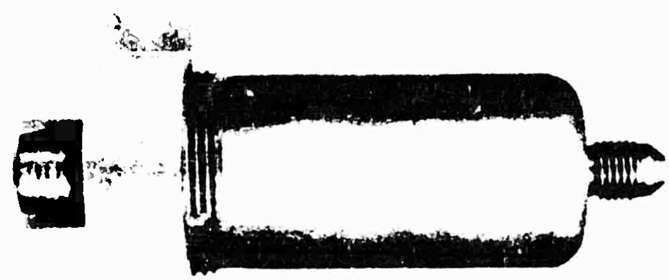

B

Figure 7. Initiator with Cartridge, M5 (T5)

A - Envelope drawing
B - Assembled view

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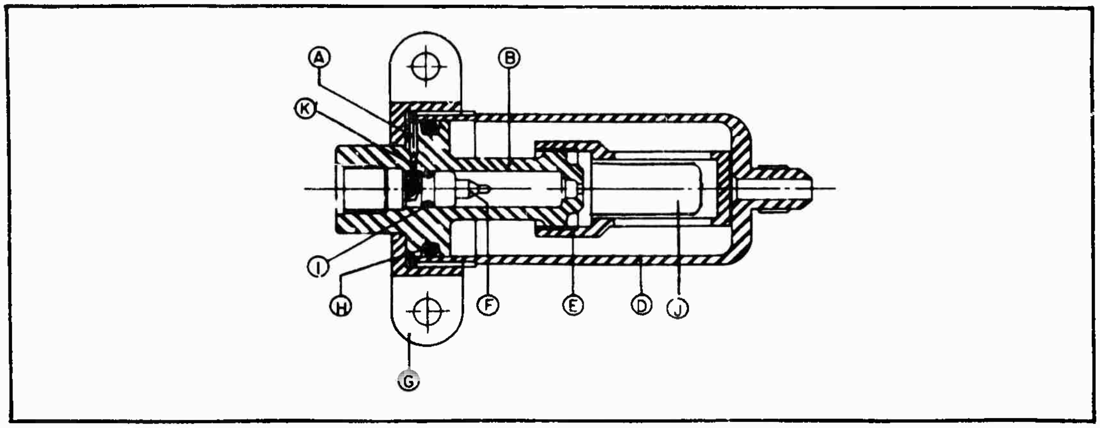

	Component	Development Drawing Number	Ordnance Drawing Number
A	Setscrew		
B	Housing, firing pin	BLX-86-7	94-3-14A
D	Chamber	ALX-86-15	94-3-14B
E	Retainer, cartridge	ALX-86-16	94-3-14C
F	Pin, firing	ALX-86-8	94-3-13A
G	Cap	BLX-86-6	94-3-13C
H	"O" ring	AN6227-B19	CKCX2501462
I	"O" ring	AN6227-B4	CKCX2501217
	Plug, entry port (for shipping only)	Commercial	94-3-12B
J	Cartridge, Initiator, M38	ALX-34-I	95-1-15
K	Pin, shear	ALX-86-14	94-3-13B
	Assembly drawing	FLX-86-1	94-3-11
	Parts list	ALX-86-2	

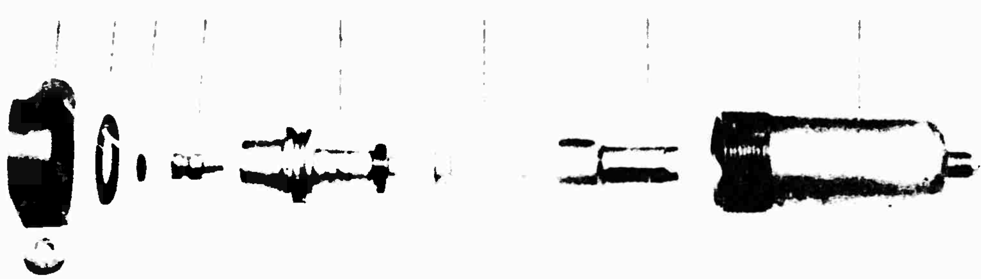

Figure 8. Cross-section drawing and exploded view, Initiator, M5 (T5)

pressure on the unsupported area of the piston. The device is initiated by propellent gas from an initiator or other source.

The ballistic performance of the M5 thruster varies with firing temperature and inertial and resistive forces operating in the direction of opposing motion of the piston.*

Assembled and exploded views of the M5 thruster are shown in Figure 9; the assembly drawing (sectional view), in Figure 10; engineering data are given in Table I. Curves showing thrust-time and thrust travel performance for the M5 thruster propelling a 323-lb weight vertically upward are shown in Figure 11.

Table I. Engineering Data, M5 Thruster

Stroke	5 in.
Bursting pressure, body	20,800 psi
Area, piston	1.0 in.^{2}
Thruster internal volume	
Initial	2.78 in.^{3}
Final	7.86 in.^{3}
Weight, total assembly	3.61 lb
Force required to unlock piston	60 lb

Note: Throughout this report mention is made of Thruster, T4E1. This nomenclature applies to the development model of Thruster, M5. There is no substantial difference between the two models.

Canopy Remover, M3

In emergency escape from high speed aircraft, to insure safety of personnel the canopy must be jettisoned prior to personnel ejection. This operation usually involves rotation of the canopy through an angular displacement and, in some types of aircraft, rectilinear displacement is also required after the rotation has been completed. The thrust and energy required for jettison are provided by a cartridge actuated device of either the thruster or canopy remover type, depending upon the requirements of the aircraft.

*Performance data for the M5 thruster fired under the conditions: locked shut; propelling mass loads vertically; and propelling mass loads horizontally, with shear pins restraining motion at the beginning and end of stroke, are presented in Reference 12.

Performance data for the M5 thruster fired in a mechanical system providing approximately constant resistive force with negligible inertia are presented in Reference 13.

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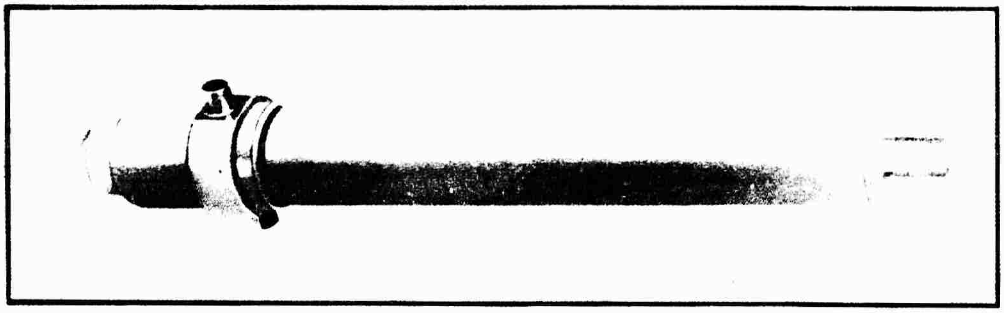
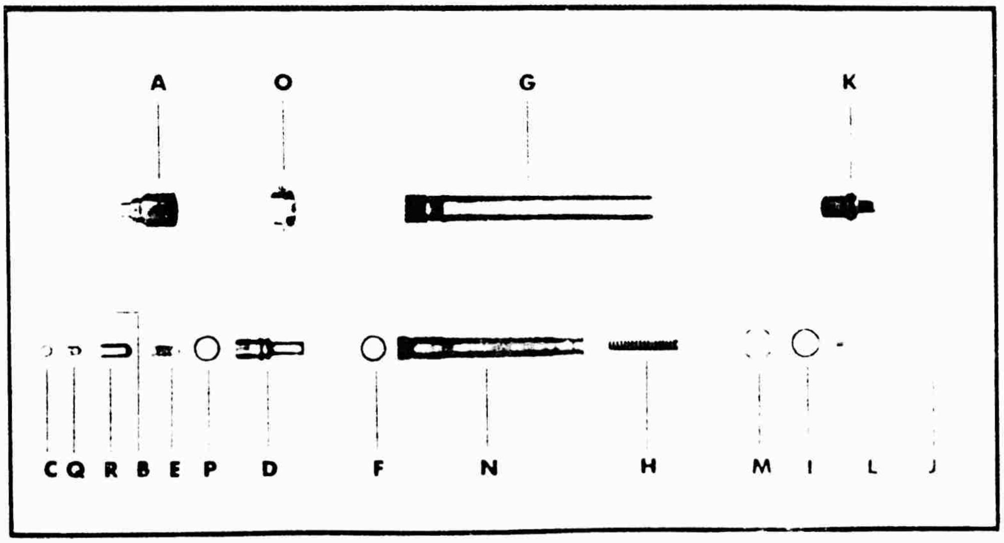
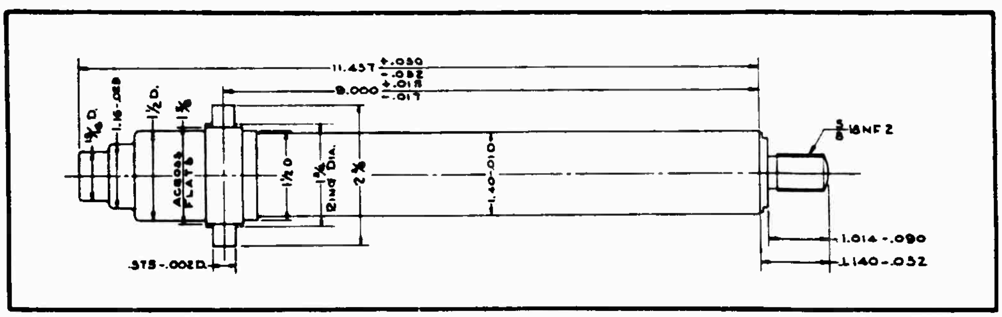


Assembled View



Exploded View



Envelope Drawing

Figure 9. Thruster, M5A1 (T4E1)

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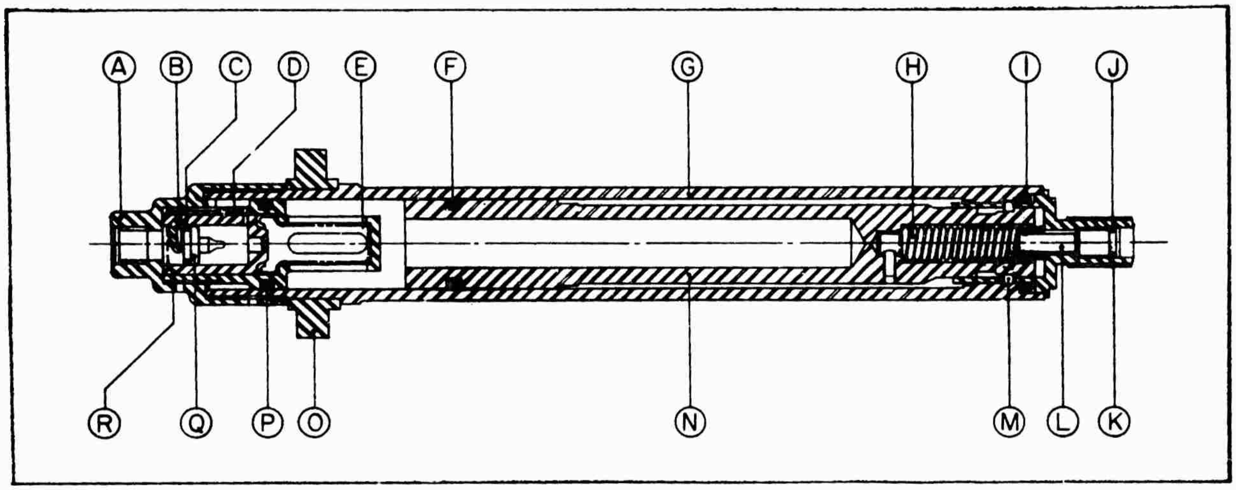

	Component	Development Drawing Number	Ordnance Drawing Number
A	Head	ALX-122-4	FB36846
B	Pin, Shear	ALX-122-10	FA 29183
C	"O" Ring	AN6227-B19	CKCX2501220
D	Retainer, Cartridge	ALX-122-11	FA 29184
E	Cartridge, CAD, M38	BLX34-1	95-1-15
F, P	"O" Ring	AN6227-B17	CKCX2501228
G	Body	ALX-122-3	FB 33430
H	Spring, Piston Locking	ALX-122-12	FA 29185
I	"O" Ring	AN6227-B17	CKCX2501162
J	"O" Ring	AN6227-B5	CKCX2501218
K	Sleeve, End	ALX-122-9	FB 35447
L	Screw, Buffer	ALX-122-18	FA 29186
M	Key	ALX-122-19	FB 34910
N	Piston	ALX-122-6	FB 35448
O	Trunnion	ALX-122-5	FA 29179
Q	Pin, Firing	ALX-122-8	FA 29181
R	Guide, Firing Pin	ALX-122-7	FA 29180
	Screw, Socket, Hex	RCTX4	Commercial
	Metal Parts Assembly	BLX122-1	FF 7433
	List of Parts & Specifications	BLX122-2	FF 7433 A
	Loading Assembly & Marking Diagram	BLX122-16	FF 7432

Figure 10. Assembly, Thruster, Cartridge Actuated, M5A1

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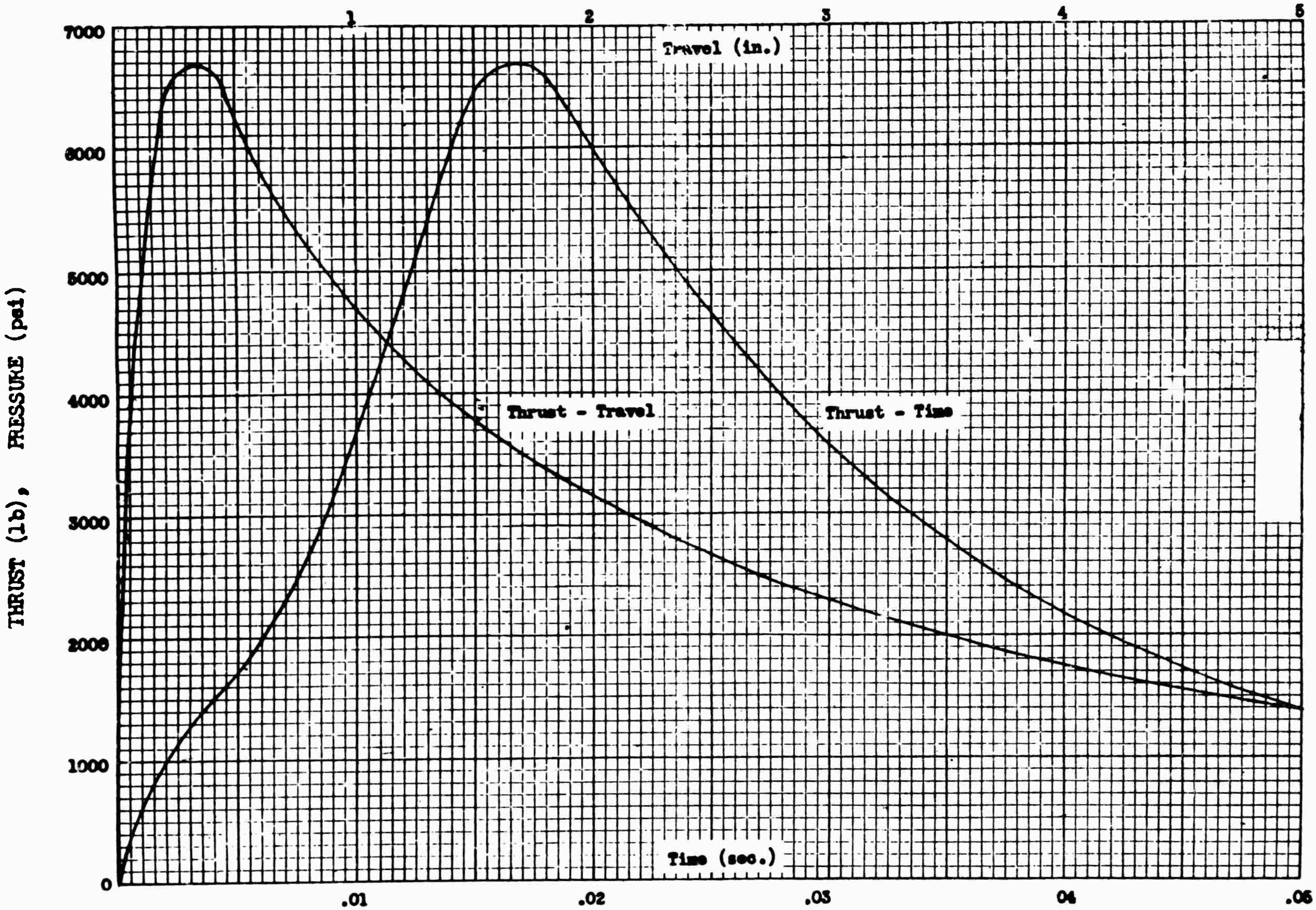

Figure 11. Thrust-time and thrust-travel relationships obtained in propelling a 323-lb mass vertically with M5 (T4E1) thruster and M38 cartridge

The M3 remover is a two-tube telescoping device consisting essentially of a firing head, cartridge, outer tube, inner tube, and base cap. In installation, the remover is mounted at both the base cap and firing head. The remover is approximately 30 inches long and has a stroke of 26 inches.

This device is initiated by propellent gas which is introduced into the firing head, from an initiator, through a transmission line. Gas pressure continues to rise in the firing head, behind the firing pin, until the shear pin is sheared by the motion of the firing pin. After pin shear, the firing pin moves forward and draws the latches in toward the center, unlocking the remover. The firing pin continues moving forward until it strikes the primer, firing the cartridge.

Representative performance curves for the M3 remover* are shown in Figures 12 and 13. The maximum thrust produced when the remover is fired locked shut is approximately equal to the maximum thrust produced when the remover is fired propelling a 300-lb load horizontally. This result is explained by the fact that the propellant is completely burned before <u>appreciable expansion</u> has taken place. This is an important factor in remover performance, for it gives assurance that in the event the canopy should jam, there will be no danger of remover rupture with its attendant personnel hazards. The assembled and exploded views of the M3 remover and the envelope drawings are presented in Figure 14; the assembly drawing and designation of components are presented in Figure 15. Engineering data for the M3 remover are given in Table II.

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*Performance data for the M3 remover, fired vertically propelling mass loads of 400, 600, 800, and 1000 lb, are presented in Reference 13.

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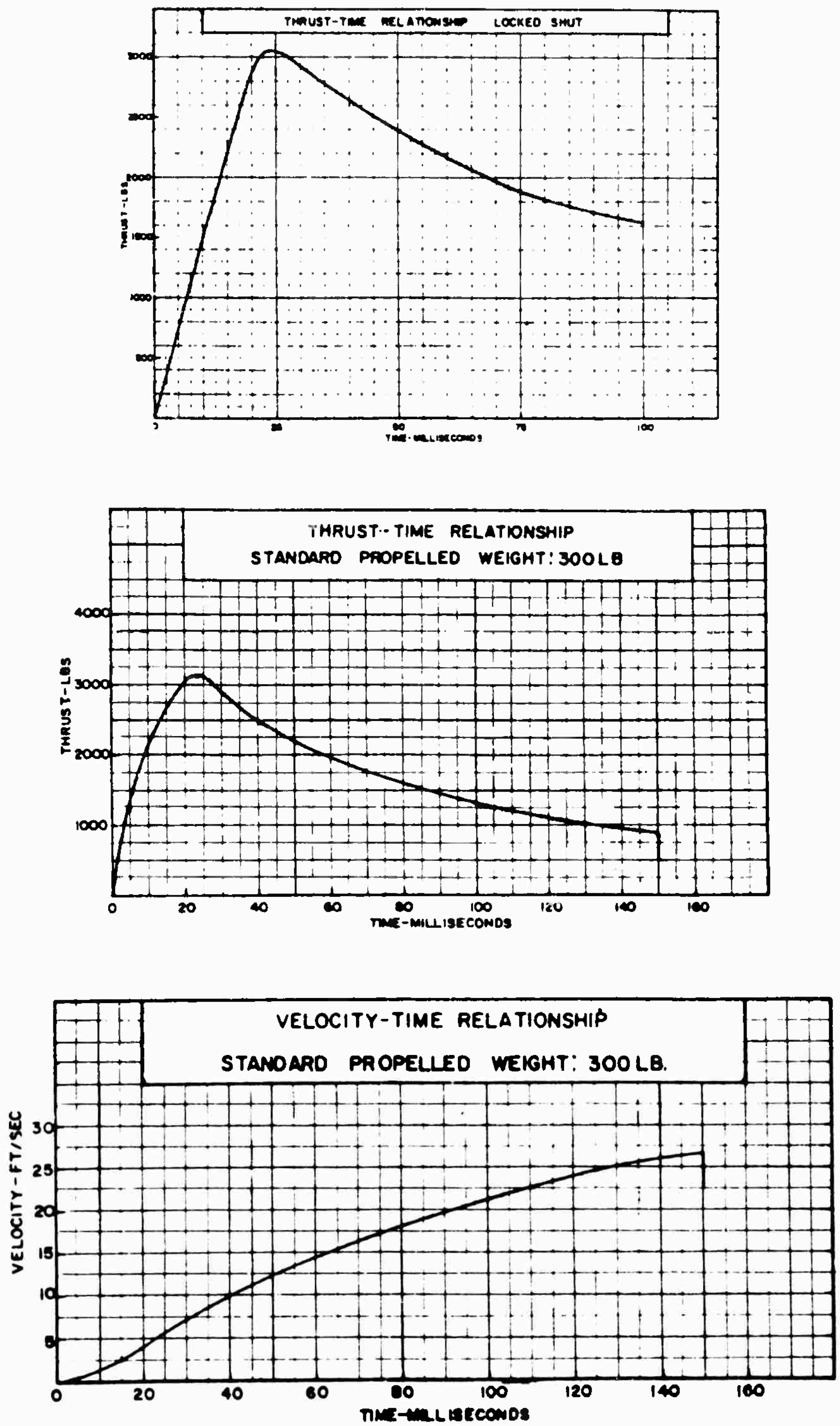

Figure 12. Performance curves, M3 remover, 70° F, horizontal firings

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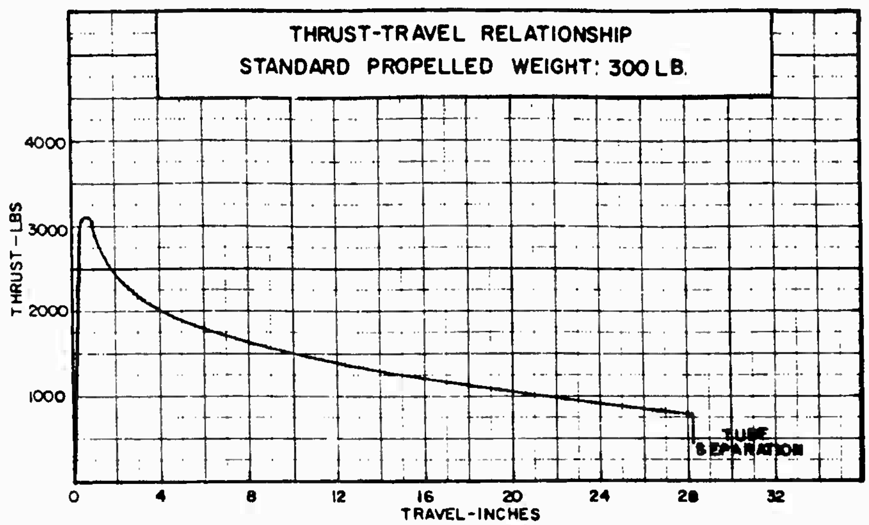

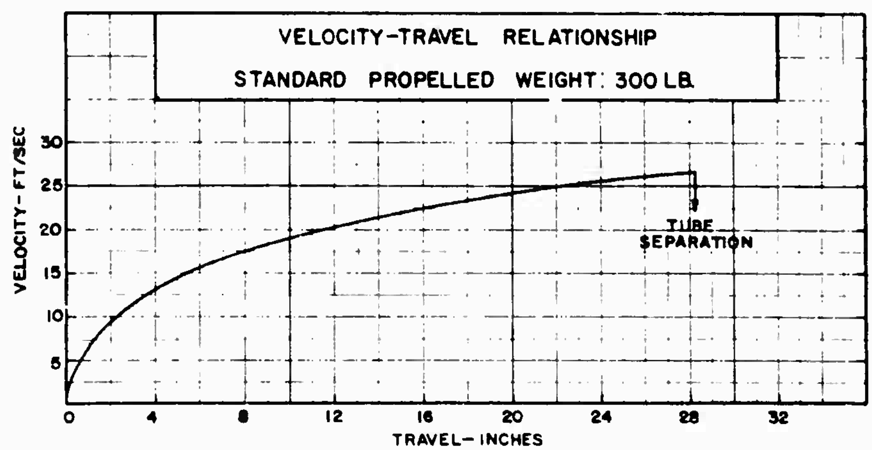

Figure 13. Performance curves, M3 remover, 70° F, horizontal firings

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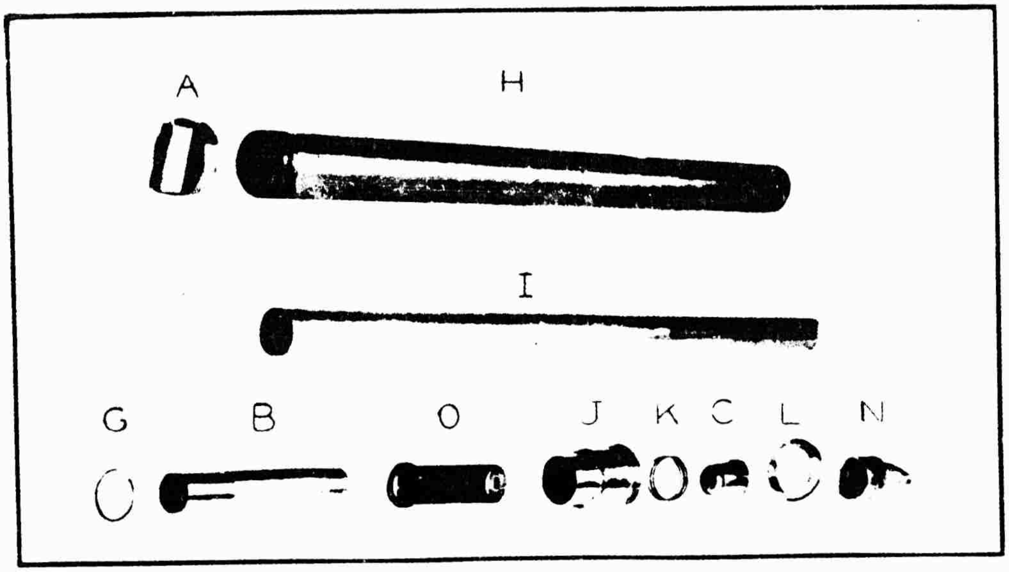
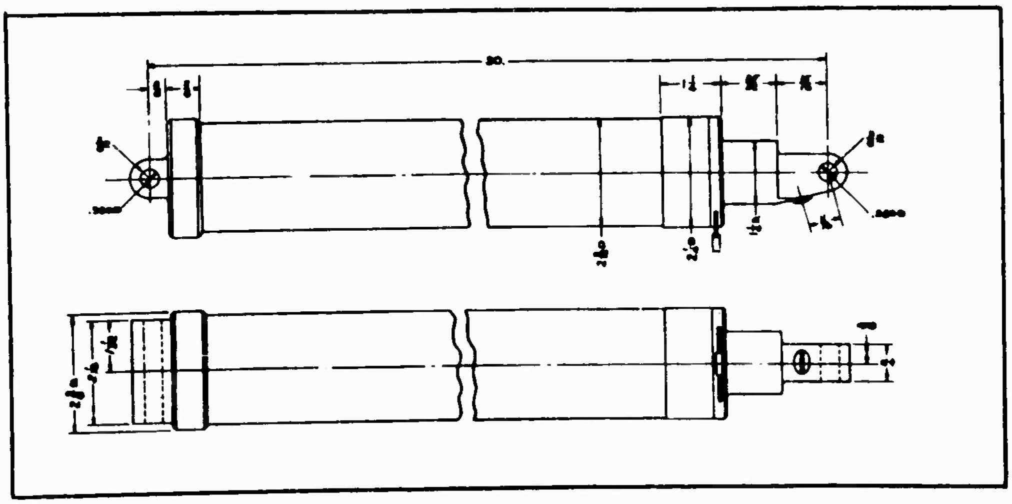


EXPLODED VIEW



ENVELOPE DRAWING

ASSEMBELED VIEW

Figure 14. M3 remover

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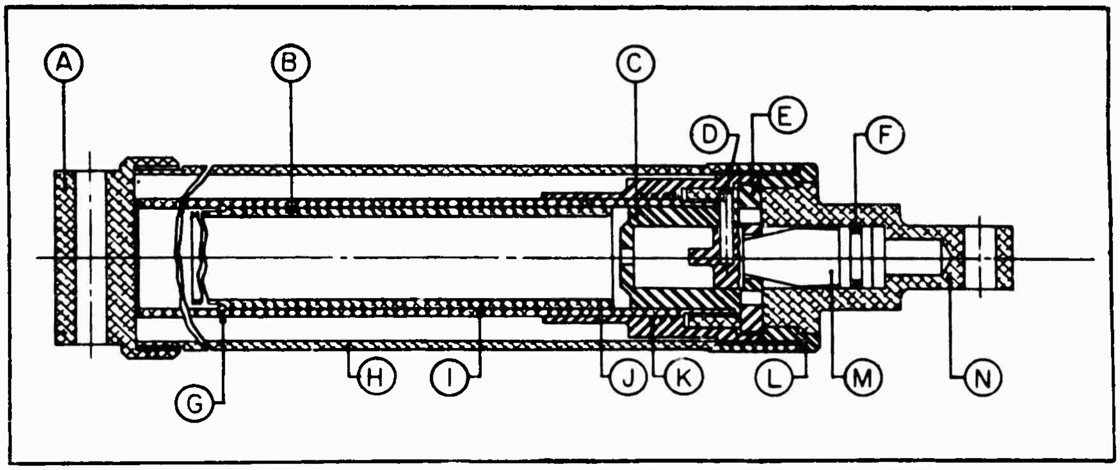

CROSS-SECTION DRAWING

	Component	Development Drawing Number	Ordnance Drawing Number
A	Cap	A7140815	94-2-13A
B	Sleeve	A7140818	94-2-13B
C	Plug	ALX-53-5	94-2-17B
D	Pin, Shear	ALX-53-10A	94-2-18C
E	Latch	ALX-53-9	94-2-17C
	Pipe Plug (for shipping only)	Commercial	94-0-3B
F	"O" Ring	AN6227-B11	CKCX2501223
G	Spring, Retaining	A7140821	94-2-13C
H	Tube, Outside	BLX-53-12	94-2-19A
I	Tube, Inside	BLX-53-11	94-2-19B
J	Tube, Bearing	ALX-53-8	94-2-18A
K	Spring	A7140819	94-0-1A
L	Ring, Stop	ALX-53-6	94-2-18B
M	Pin, Firing	ALX-53-7	94-1-13C
N	Block	ALX-53-4	94-2-17A
O	Cartridge, CAD, M31A1	BLX-53-1	75-1-290
	Assembly Drawing	ALX-53-2	94-2-16A
	Parts List		

Figure 15. Assembly, M3 remover

Table II. Engineering Data, M3 Remover

Stroke, total	26.0 in.
Area, inside tube	1.58 $in.^2$
Weight	
Inside tube	0.9 lb
Outside tube	1.3 lb
Total assembly	4.4 lb
Bursting pressure	
Inside tube	6350 psi
Outside tube	4670 psi
Remover internal volume	
Initial (cartridge open)	69 $in.^3$
Final (tube separation)	110 $in.^3$
Safe structural strength*	
Compression	8000 lb
Tension	2000 lb

*Based on specification; values in excess of this have been obtained in test.

Cartridge, CAD, M38

Cartridge, CAD, M38, is used in the M3 initiator, M5 initiator, and M5 thruster. This cartridge is actuated by a percussion-sensitive primer (No. 26) and contains, as propellant charge, 2.8 gm M5 propellant (Lot 7944) and 1 gm black powder (Grade A4).

The assembled cartridge includes the aluminum cartridge case with propellant and igniter, the head assembly with primer, and auxiliary components to provide sealing.

The primer is sealed with the aluminum disc which covers the primer and retainer. In assembly, the lip of the cartridge case is crimped around the "O" ring, which is seated on the retainer. This arrangement provides adequate sealing and is effective against a pressure differential of 12 psi. The assembly drawing (cross-section view) of the M38 cartridge and the exploded view of its components are presented in Figure 16. Engineering data for this cartridge are given in Table III.

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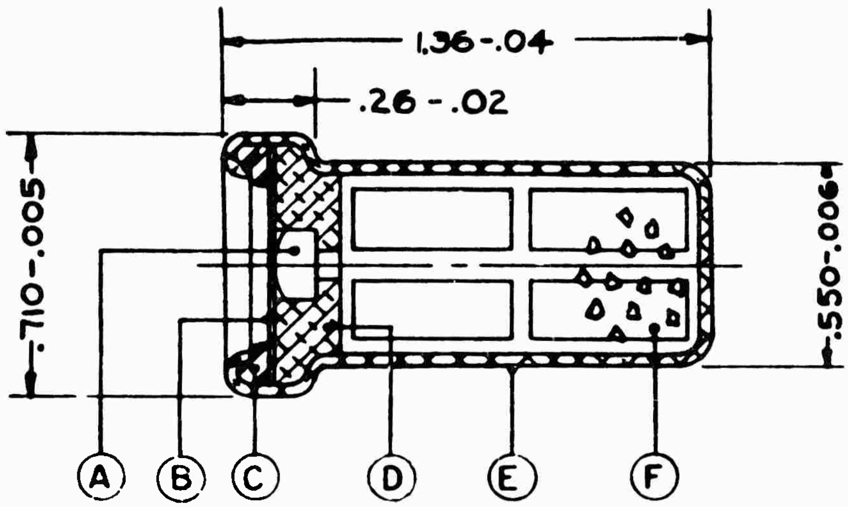
R-1347



	Component	Development Drawing Number	Ordnance Drawing Number
A	Primer	74-2-42	A5000131
B	Disc	ALX-34-3	95-1-16B
C	"O" Ring	AN6227-9	CKCX2501221
D	Retainer, Primer	ALX-34-5	95-1-16A
E	Case	ALX-34-4	95-1-16C
F	Propellant & Igniter		
	Assembly Drawing	FLX-34-1	95-1-15A

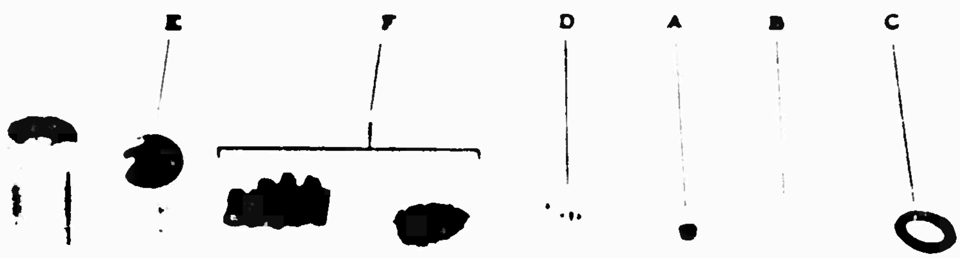


Figure 16. Assembly and exploded view of the M38 cartridge

Table III. Engineering Data for Cartridge, CAD, M38

Propellant	
Charge	2.8 gm
No. of perforations	7
Diameter, outside	0.195 in.
Diameter, perforation	0.0125 in.
Length	0.462 in.
Web	0.039 in.
Specification	JAN-P-323
Type	M5
Lot (Radford Ordnance Works)	7944
Composition (nominal %)	
Nitrocellulose (13.22% N)	75.50
Nitroglycerin	20.00
Barium nitrate	1.50
Potassium nitrate	1.00
Graphite	0.75
Diphenylamine	0.25
Dinitrotoluene	1.00
Igniter	
Charge	1.0 gm
Type	Black powder
Grade	A4
Specification	JAN-P-223
Primer	
Charge	0.4 gr
Type	Percussion
Designation	No. 26
Composition	FA 70
Drawing	A5000131

Note: Experimental M38 cartridges were loaded with M2 propellant (Radford Ordnance Works), Lot 5280-42. Propellant grain dimensions follow.

Diameter	0.203 in.
Diameter, perforation	0.014 in.
Length	0.432 in.
Web	0.040 in.

Cartridge, CAD, M31A1

Cartridge, CAD, M31A1, is used in the M3 aircraft canopy remover. This cartridge has a percussion sensitive primer (artillery type M61) and contains a propellant charge of 23 gm M2 propellant (Lot HPC 4281-41), and 25 gr black powder (grade A1) which serves as the igniter.

The assembled cartridge includes the aluminum cartridge case with propellant charge, the head assembly with primer and igniter, and auxiliary components to provide sealing.

Sealing of the primer case is provided by an aluminum disc which covers the cartridge head, retaining ring, and firing plug. In assembly, the lip of the cartridge case is crimped around an "O" ring seated on the disc above the cartridge head. This sealing arrangement is effective against a pressure differential of 12 psi. The assembly drawing (cross-section view) of the M31A1 cartridge and an exploded view of the components are presented in Figure 17. Engineering data are presented in Table IV.

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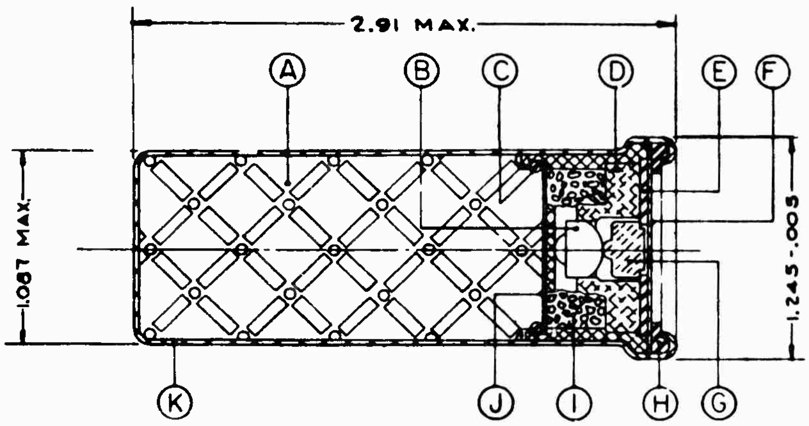
R-1347



	Component	Development Drawing Number	Ordnance Drawing Number
A	Propellant		
B	Primer	74-2-42	74-2-42
C	Spring, Retaining	ALX23-6	75-1-291F
D	Head	ALX23-5	75-1-291B
E	Ring, Retaining	ALX23-9	75-1-291G
F	Disc	ALX23-7	75-1-291H
G	Plug, Firing	74-2-78M	75-1-291L
H	"O" Ring	AN6227B-18	AN6227B-18
I	Igniter		
J	Disc, Igniting Charge	ALX23-7	75-1-291E
K	Case	ALX23-11	75-1-291A
	Assembly Drawing	ALX23-1	75-1-290
	Parts List	ALX23-2	

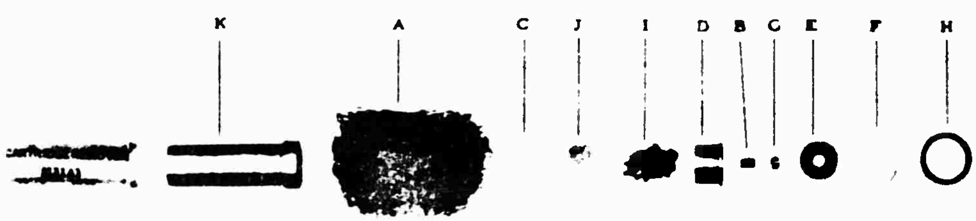


Figure 17. Assembly and exploded view of the M31A1 cartridge

Table IV. Engineering Data, M31A1 Cartridge

Propellant	
Charge	23.0 gm
No. of perforations	1
Diameter, outside	0.073 in.
Diameter, perforation	0.007 in.
Length	0.243 in.
Web	0.033 in.
Specification	JAN-P-323
Type	M2
Lot (Hercules Powder Co.)	4281-41
Composition (nominal %)	
Nitrocellulose (13.22% N)	75.50
Nitroglycerin	20.00
Barium nitrate	1.50
Potassium nitrate	1.00
Diphenylamine	0.75
Graphite	0.25
Dinitrotoluene	1.00
Igniter	
Charge	25.0 gr
Type	Black powder
Grade	A1
Specification	JAN-P-223
Primer	
Charge	1.0 gr
Type	Percussion
Designation	Artillery type
Composition	FA 70
Drawing	74-2-42

Note: Experimental M31A1 cartridges were loaded with M2 propellant (Radford Ordnance Works), Lot 5316. Propellant grain dimensions follow.

Diameter	0.069 in.
Diameter, perforation	0.009 in.
Length	0.25 in.
Web	0.030 in.

EXPERIMENTAL PROCEDURE

Prior to acceptance of an escape system proposed for aircraft installation, tests must be performed to establish reliability for the system as a whole and to obtain a performance history of the system operated under the most severe conditions possible in service. Standard cartridge actuated devices are used in this escape system. A performance history for each device has been established by numerous tests under test conditions in accordance with the specifications. When used as components of this escape system the device must operate satisfactorily under conditions peculiar to installation in the aircraft. These conditions are often quite different from those based on specifications. It must be established by system tests that the cartridge actuated devices can be reliably initiated within the escape system and that their performance under conditions of service will be satisfactory.

The evaluation program was conducted in five phases. The specific objectives and experimental procedure followed in each phase are explained in detail below.

Test Procedure

Phase A: Preliminary Performance Evaluation of Transmission System

Prior to performance evaluation of the canopy jettison system as a whole, a program was established to test certain portions of the system whose performance appeared to be somewhat uncertain. The system was accordingly divided into three subsystems, each of which is independent of the others as far as gas transmission is concerned. They are: ground release control, pilot's control, and remover operation. Details of the tests follow.

Ground Release Control System: M3 initiator through 9 in. stainless steel tubing, union bulkhead (AN832-4), 50 in. flexible hose (AN6271-4), check valve (AN6249-4),* cross (AN937-4) with exposed sides plugged, union (AN815-4), 12 in. flexible hose (AN6271-4), union (AN815-4), to T4E1 thruster, with M38 cartridge (primed only).

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*Fitting is described in Reference 13.

(a) Five function tests were conducted with system conditioned at -65° F.

(b) Thruster was replaced in system with pressure block (volume 0.062 in.^{3}); the system, conditioned at -65° F, was fired five times.

Pilot's Control System: M3 initiator through 10 in. flexible hose (AN6271-4), Wiggins disconnect, 72 in. flexible hose (AN6271-4), 45° elbow (AN837-4), 14 in. flexible hose (AN6271-4), check valve (AN6249-4), cross (AN937-4) with exposed sides plugged, union (AN815-4), 12 in. flexible hose (AN6271-4), union (AN815-4), to Thruster, T4E1, with M38 cartridge (primed only).

(a) Five function tests were conducted with system conditioned at -65° F.

(b) Thruster was replaced in system with pressure block (volume 0.062 in.^{3}); five rounds were fired with system conditioned at -65° F.

Remover Operation System: M3 initiator through 23.5 in. flexible hose (AN6271-4), Wiggins disconnect, 11.5 in. flexible hose (AN6271-4), bulkhead union (AN832-4), flexible hose (AN6271-4), union (AN815-4), 18 in. flexible hose (AN6271-4), 45° elbow (AN837-4), 12.5 in. flexible hose (AN6271-4), nipple (AN816-4), to M3 remover with M31A1 cartridge (primed only). Pressure in the firing block of the remover was recorded.

(a) Eight rounds were fired with the system at -65° F.

(b) Three rounds were fired with system at ambient (room) temperature.

Phase B: Performance Evaluation of Remover, M3

A series of test firings was conducted in which T6 removers (approximating in performance the M3 remover) were fired on the horizontal test track* propelling 300-, 400-, and 500-lb weights. The loaded removers were conditioned at extreme temperatures (-65° and 160° F), prior to firing, for a minimum of 3 hours.

The removers were loaded with the cartridge containing the charge used in the M3 remover (Cartridge, M31A1; propellant charge, 23 gm RAD 5316; igniter, 25 gr A1 black powder). Internal pressure and

*For information concerning the horizontal test track, see Reference 3.

velocity at tube separation were recorded. Thrust and acceleration were calculated from the pressure records. Travel vs time performance was obtained by double integration of the acceleration-time performance information. The integration process consisted of transferring the information from the pressure-time oscillogram to punched cards, and numerically integrating with a digital computer.

A program of test firings was conducted in which M3 removers were operated on the vertical test track propelling 300-, 400-, and 500-lb loads. The removers with cartridge were conditioned for a minimum of 3 hours at -65° F prior to firing. Pressure-time performance and travel of the propelled mass as a function of time at positions of one inch were recorded. Velocity was calculated from travel information.

Phase C: Performance Evaluation of M5 (T4E1) Thruster

A series of test firings was conducted under special test conditions which approximated conditions of service. In these tests the thruster propelled a weight of 20 lb horizontally. A steel shear pin, rated to shear at 1000 lb force, was provided to give an initial resistance. The thruster was instrumented to record internal pressure and piston stroke as functions of time. Firings were conducted as follows.

(a) Five rounds with thruster conditioned at -65° F for a minimum of 3 hours prior to firing.

(b) Five rounds with thruster conditioned at 160° F for a minimum of 3 hours prior to firing.

Phase D: Evaluation of Operational Reliability of Remover, M3, under Tension Loading Conditions

Under certain conditions of plane attitude, severe airframe warpage can occur. Under such circumstances the remover may be required to support tension loads of as much as 10,000 lb. It was considered necessary to investigate the possibility that the remover firing mechanism cannot be operated with reliability while the remover is in tension. A program of tests was conducted in which the remover was initiated while under tension. To simulate service installation, the remover was initiated with an M3 initiator through flexible hose. The pressure-time relation in the remover firing block was recorded.

In these tests the remover was assembled with an M31A1 cartridge containing a primer but no propellant. The remover was placed in tension by means of a special mounting frame, screw jack, and dynamometer. Firings were conducted as follows.

System: M3 initiator, 2.5 ft flexible hose (AN6271-4), 90° elbow with pressure station,* to M3 remover.

(a) Four rounds for each tension load, commencing with zero and proceeding by increments of 750 lb to 4500 lb tension, and four rounds at 5500 lb tension. The remover, initiator, and connecting flexible hose were conditioned at -65° F for a minimum of 3 hours prior to firing.

(b) Same as (a) except that the systems were conditioned at 160° F.

(c) Three rounds for each tension load, commencing with 6500 lb and proceeding by increments of 1000 lb and 9500 lb tension. The remover, initiator, and connecting flexible hose were conditioned at -65° F for a minimum of 3 hours prior to firing.

(d) Same as (c) except that the systems were conditioned at 160° F.

System: M3 initiator, flexible hose (AN6271-4), 90° elbow with pressure station, to M3 remover. The remover was placed in 9000 lb tension. Systems were conditioned at -65° F for a minimum of 3 hours prior to firing.

(a) One round using 2.5 ft of flexible hose.

(b) One round using 6 ft of flexible hose.

(c) One round using 9 ft of flexible hose.

(d) Six rounds using 10 ft of flexible hose.

Phase E: Final Performance Evaluation of Transmission System

The final transmission system evaluation consisted of test firing ten canopy jettison transmission systems. To facilitate testing of the system it was divided into four independent subsystems: pilot's control, navigator's control, ground release control, and booster initiator (M5) operation. Each subsystem was tested separately. The components of each system are given in detail below.

Ground Release Control System: Same as given on p 28 with this exception: "90° elbow with pressure station" replaces the last-mentioned "union (AN815-4)."

Ten systems were conditioned at -65° F for a minimum of 3 hours, and then fired. Pressure in the thruster firing head was recorded.

*This fitting is described in Reference 14.

Navigator's Control System: M3 initiator through 10 in. flexible hose (AN6271-4), 27 in. flexible hose (AN6271-4), check valve (AN6249-4), cross (AN937-4) with exposed sides plugged, union (AN815-4), 12 in. flexible hose (AN6271-4), 90° elbow with pressure station, to T4E1 thruster, with M38 cartridge (primed only).

Ten systems were conditioned at -65° F for a minimum of 3 hours, and then fired. Pressure in the thruster firing head was recorded.

Pilot's Control System: Same as given on p 29 with this exception: "90° elbow with pressure station" replaces the last-mentioned "union (AN815-4)."

Ten systems were conditioned at -65° F for a minimum of 3 hours, and then fired. Pressure in the thruster firing head was recorded.

Booster Initiator Operation System: M3 initiator through 26 in. flexible hose (AN6271-4), Wiggins disconnect, 11.4 in. flexible hose (AN6271-4), bulkhead union (AN832-4), 73 in. flexible hose (AN6271-4), 90° elbow with pressure station, to M5 initiator.

Ten systems were conditioned at -65° F for a minimum of 3 hours and then fired. Pressure at the initiator inlet port was recorded.

These tests supplied a performance history for ten complete canopy jettison systems for the B-57B aircraft.

Instrumentation and Test Apparatus

The ballistic parameters obtained in the test programs of this project were internal pressure, time, travel of propelled load, and velocity. With the exception of velocity, the ballistic parameters were recorded as voltage information impressed on an oscilloscope. A special moving film camera was used to obtain a permanent record of the signal.

All pressure-time performance information was obtained by use of a piezoelectric pressure transducer in conjunction with electronic amplifying equipment and an oscilloscope. Time was recorded by blanking the oscilloscope beam with an oscillating voltage of fixed frequency.

In the test firings associated with the performance evaluation of the M5 thruster, electrical contact was made at positions one-tenth inch apart, to record travel of the thruster piston.

The vertical test tower was used for tests in which the M3 remover was fired vertically upward, propelling various loads. Instrumentation techniques used in connection with the test tower include use of a system of electromagnetic pickups arranged to record travel in increments of one inch. As the carriage with load passes a pickup, it changes the magnetic reluctance of the pickup circuit. An electromotive force is thus generated. This signal is fed into a simple resistance-capacitance integrating circuit and the oscilloscope. The output voltage information from the travel recording circuits consists of a continuous signal of varying amplitude. The function form is characterized by a series of maxima which approximate cusps. Each maximum represents completion of one inch of travel. Pressure, time, and travel information are recorded simultaneously. A representative oscillo-record is shown in Figure 18.

In test firings with the T6 remover on the horizontal test track, velocity at tube separation was measured. Velocities were computed from counter chronograph measurements of the travel time of the carriage over a specific distance (5 ft). Electrical contacts at each end of the base line served as travel markers.

In aircraft installations, catapults and canopy removers are frequently placed under severe longitudinal stress by external loads applied through radial acceleration and airframe warpage due to aerodynamic loading of the canopy. It is often necessary to determine what effect such external loads have on the successful operation of these units. To facilitate the performance of such test firings, a special mounting frame with adapters was designed and fabricated for placing removers and catapults under loads (tension and compression) through their normal mounting points. In a test firing, the units are under load only while locked. Since the cartridge actuated devices vary in size and type of mounting, different adapters are required for each type. The mounting frame and adapters used in test firings of the M3 remover appear in Figure 19 and 20.

The mounting frame consists of two columns which support three parallel beams. The beams have mounting holes into which adapters are fitted, supporting the unit to be tested. In test firings of the M3 remover, only the beams at either end are fitted with adapters. The center beam serves as a guide only. The pieces required to locate the remover in the fixture and apply tension loading are displayed on the right in Figure 20. From top to bottom they are as follows.

(a) Clevis, with 3/4 in. diameter pin to engage the dynamometer. It is threaded at one end to receive a nut for longitudinal adjustment. A thrust bearing is provided for ease in turning the nut when applying loads.

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R-1347

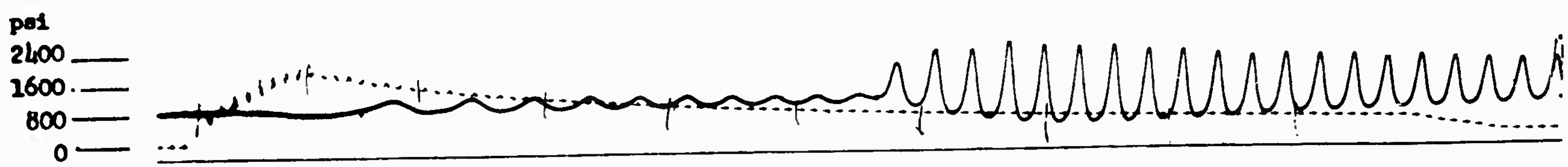

Figure 18. Oscillo-record of pressure of performance of M3 remover propelling 500-lb weight on vertical test tower at -65° F. Pressure curve shown as broken line; breaks indicate 0.0025-second intervals. Each peak of solid curve indicates completion of one inch of travel

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R-1347

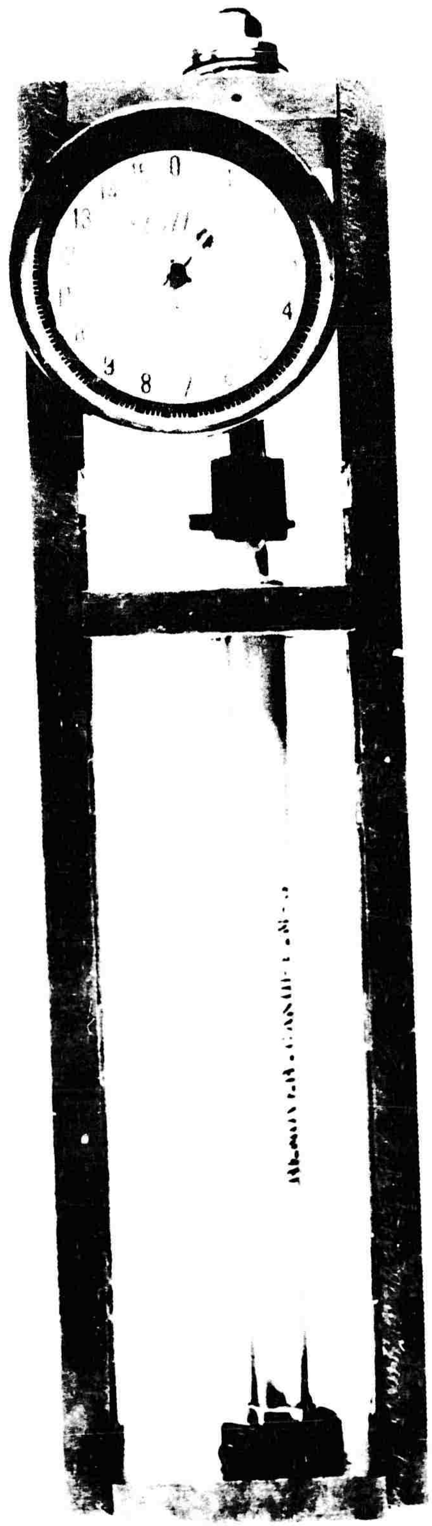

Figure 19. M3 remover installed in tension test fixture

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R-1347

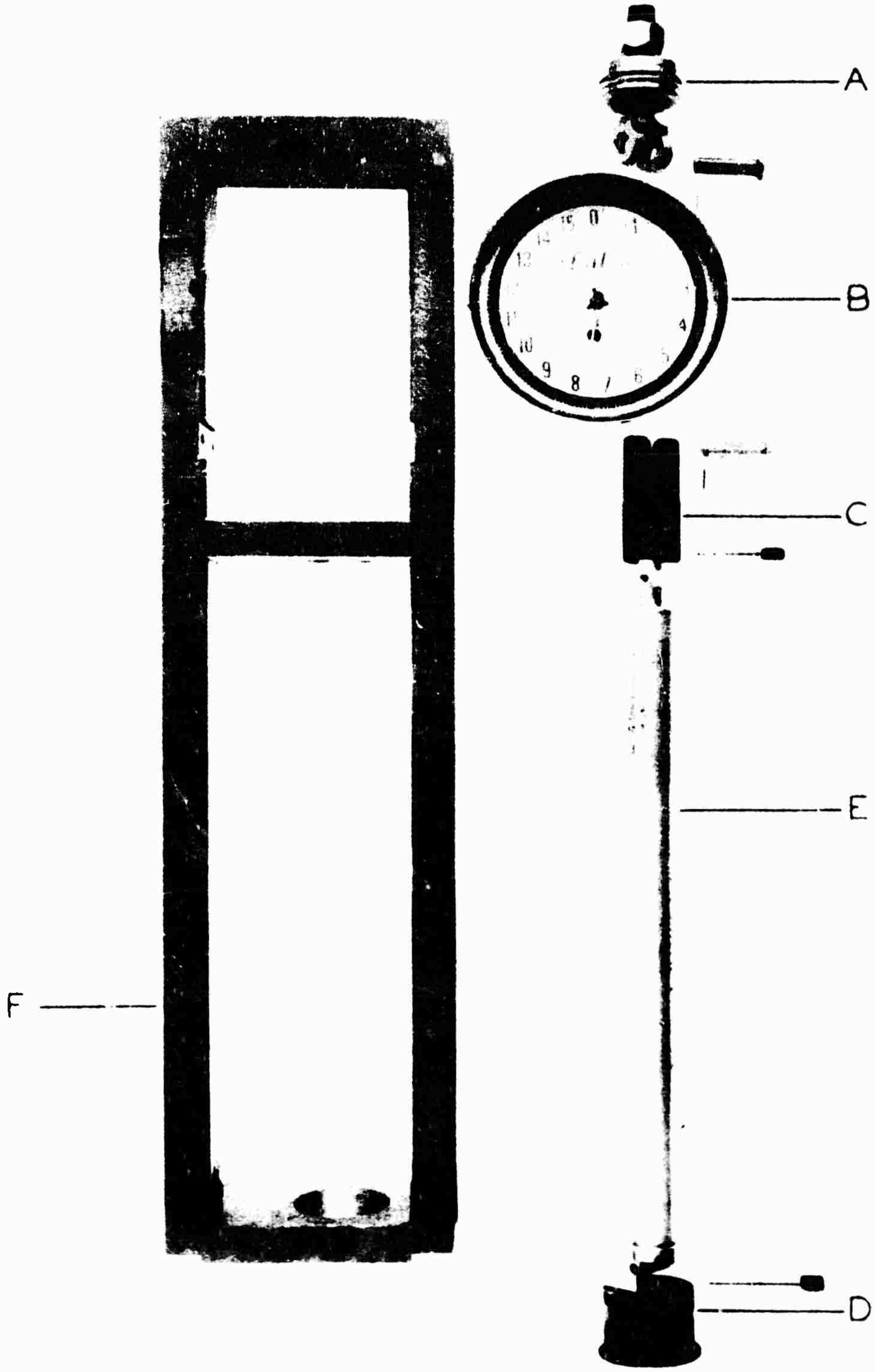

Figure 20. Adapter required for testing Remover with Cartridge, M3

A - Clevis
B - Dynamometer
C - Link
D - M3 Remover
E - Cap
F - Mounting frame

(b) Dynamometer, 0 to 15,000 lb capacity, for measuring the load applied.

(c) Link, with a 3/4 in. diameter pin at one end to locate the dynamometer and, in the opposite end, a 3/8 in. diameter pin to position the blade of the remover block. The link is in two parts, joined by a single bolt, permitting rotation of the ends. This allows proper alignment when a gage is used to record pressures in the firing head.

(d) M3 remover

(e) Cap, with a 3/8 in. pin to provide proper trunnion mounting at the base of the remover.

(f) Mounting frame.

TEST RESULTS AND DISCUSSION

The tests performed in the evaluation of the escape eystem proposed for the B-57B aircraft have been described under section "Experimental Procedure." The results of the evaluation program are presented in detail below. Each phase is treated separately; round by round data follow in the Appendix.

Phase A: Preliminary Performance Evaluation of Transmission System

The tests conducted in this phase were to evaluate the performance of the various independent transmission subsystems which comprise the canopy jettison system, as originally proposed. A summary of the results follows.

Ground Release Subsystem: The five function tests all resulted in initiation of the thruster. The performance of this subsystem is summarized as follows.

Peak Pressure (psi) in Pressure Block (5 Test Firings)		
Maximum	Minimum	Average
1560	1480	1500

Pilot's Control Subsystem: The five function tests all resulted in initiation of the thruster. The performance of this subsystem is summarized as follows.

Peak Pressure (psi) in Pressure Block (5 Test Firings)		
Maximum	Minimum	Average
1360	1050	1190

On the basis of these tests it was concluded that the thruster could be reliably initiated in these subsystems.

Remover Operation Subsystem: In none of the eight test firings with this subsystem conditioned at -65° F was the remover initiated. The performance is summarized below.

Peak Pressure (psi) in Remover Firing Block (8 Test Firings)

Maximum	Minimum	Average
870	440	630

In two of the three test firings at ambient temperature, the remover was initiated. In the third test firing the remover was not initiated; the shear pin showed evidence of partial shear. The peak pressures recorded in both successful firings were also the pressures at pin shear; their values were 1020 psi and 1060 psi, respectively. The peak pressure recorded in the third test was 1100 psi.

It was concluded on the basis of both the pressure data and the record of unsuccessful initiation that the M3 remover could not be reliably initiated in the remover operation subsystem. It was suggested by Frankford Arsenal personnel that an M5 initiator be introduced into the subsystem as a booster, thus forming two subsystems. Thus suggestion was adopted and in the presently proposed escape system for the B-57B aircraft the M3 remover is initiated by an M5 initiator through 16 in. flexible hose with fittings (Figure 1). This modified system is evaluated under Phase E.

Phase P: Performance Evaluation of Remover, M3

In this phase of the evaluation program test firings were conducted to investigate the performance of the M3 remover propelling various loads. From the data obtained it may be seen that

(a) Peak thrust performance is practically independent of the weight propelled and the position in which the remover is fired, although the performance increases with firing temperature.

(b) Velocity and mechanical energy output are decreased by increasing the weight propelled. Both are significantly lower when the remover is fired in the vertical position. Greater velocity and mechanical energy are developed when the remover is fired at the higher temperature. The data are summarized in Tables V and VI.

Table V. T6 Remover Propelling Mass Load Horizontally
(5 Firings for each Condition)

Propelled Weight (lb)	Temp (°F)	Peak Thrust (lb) Max	Min	Avg	Velocity (f/s) Max	Min	Avg	Mechanical Energy Developed (ft-lb) Max	Min	Avg
300	-65	3390	3040	3240	25.5	24.2	24.7	3140	2830	2970
300	160	3840	3700	3770	27.0	26.0	26.5	3540	3270	3420
400	-65	3570	3210	3340	21.4	20.3	20.7	2930	2630	2760
400	160	3790	3610	3700	22.2	21.3	21.8	3140	2910	3040
500	-65	3250	3040	3150	18.2	17.1	17.1	2700	2360	2530
500	160	3460	3710	3630	19.3	18.7	19.1	2940	2770	2900

Table VI. M3 Remover Propelling Mass Load Vertically Upward
(10 Firings for each Condition)

Propelled Weight (lb)	Temp (°F)	Peak Thrust (lb) Max	Min	Avg	Velocity (f/s) Max	Min	Avg	Mechanical Energy Developed (ft-lb) Max	Min	Avg
300	-65	3320	2830	3030*	20.3	18.9	19.6*	2660	2390	2510*
400	-65	3070	2870	2980	15.7	14.7	15.1	2460	2260	2350
500	-65	3100	2820	3000	12.1	10.2	11.2	2260	1920	2100

Note: The mechanical energy developed represents the sum of kinetic and gravitational potential energy of the propelled mass at tube separation. In vertical firings the potential energy is considered zero at the origin of motion.

*Average of 9 test firings

Performance curves for representative test firings of the M3 remover fired in the horizontal position are presented in Figures 21 to 26, inclusive. As Figures 23 and 24 show, the remover develops maximum thrust before any appreciable motion (and volume change) has taken place. Since the maximum thrust developed is largely dependent upon the volume in which the propellant burns, it would be expected that peak thrust performance is practically independent of the weight propelled. The variation of peak thrust with firing temperature is not so easily explained. However, the difference is believed to be caused in part by (a) increase in rate of combustion of the propellant, leaving less time for cooling (compare Figures 21 and 22), and (b) decrease in the rate of heat dissipation to the walls of the remover at the higher firing temperature.

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R-1347

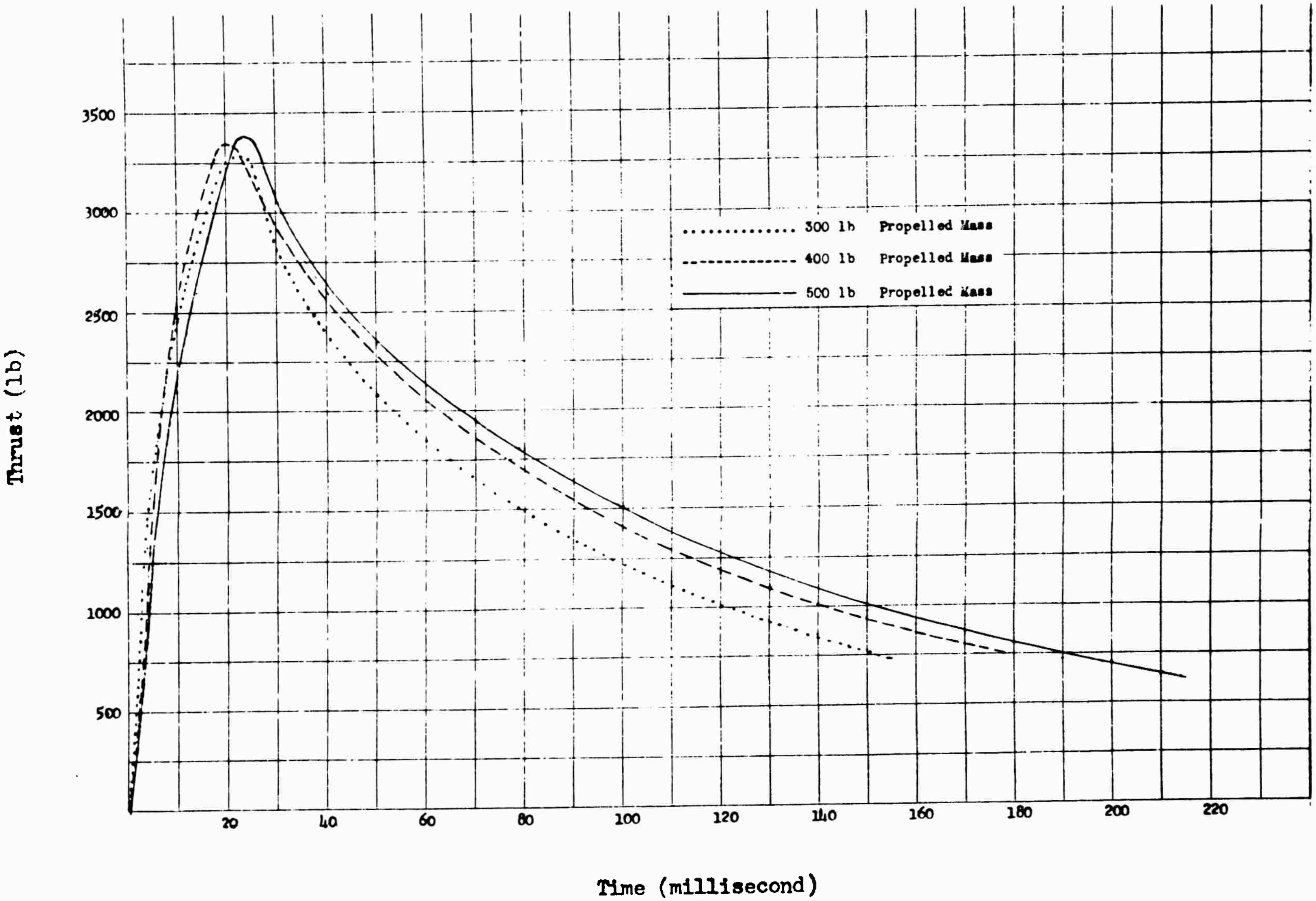

Figure 21. Representative thrust-time performance curves, T6 remover, propelling specific loads horizontally; firing temperature, -65°F

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R-1347

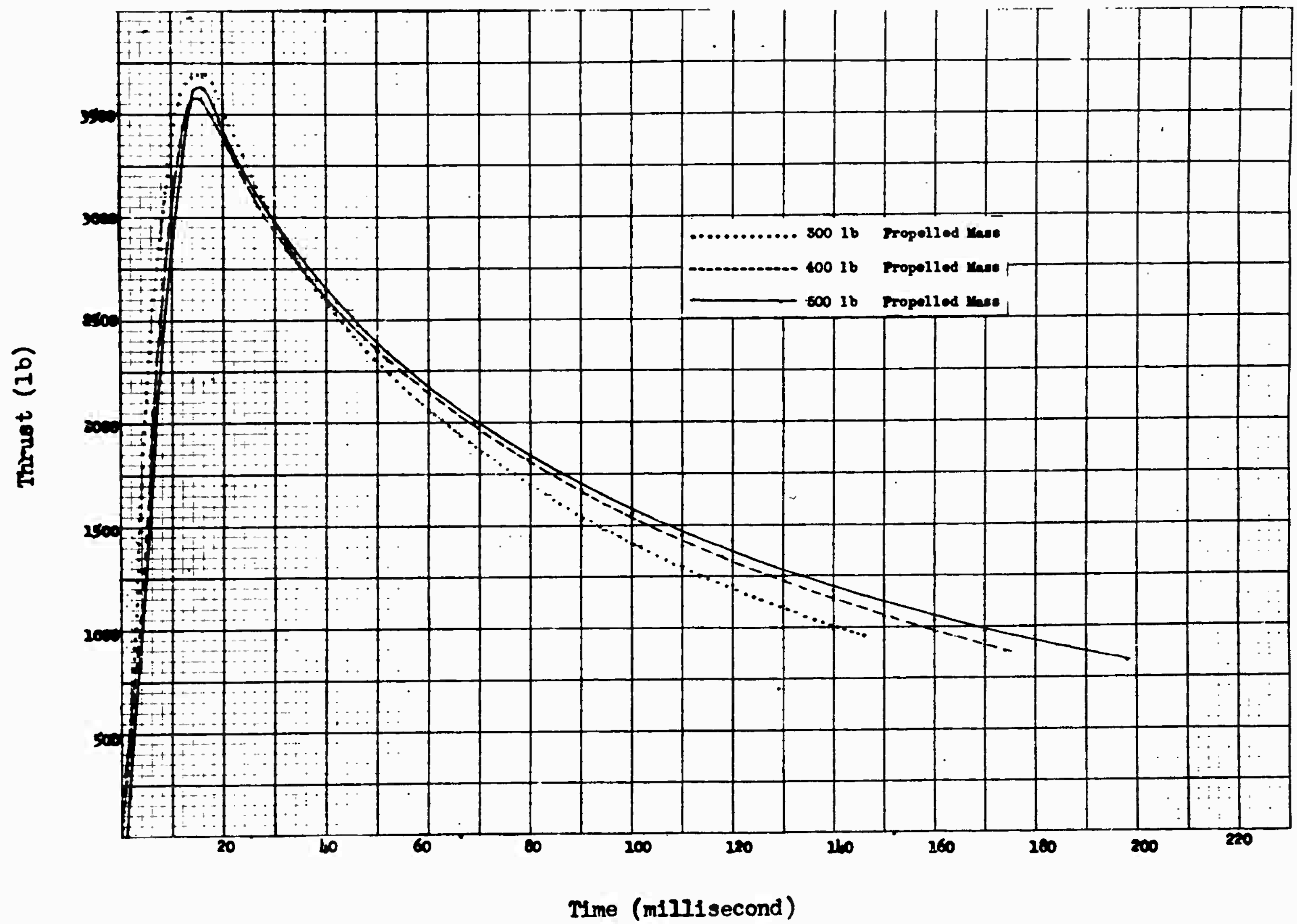

Figure 22. Representative thrust-time performance curves, T6 remover, propelling specific loads horizontally; firing temperature, 160° F

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R-1347

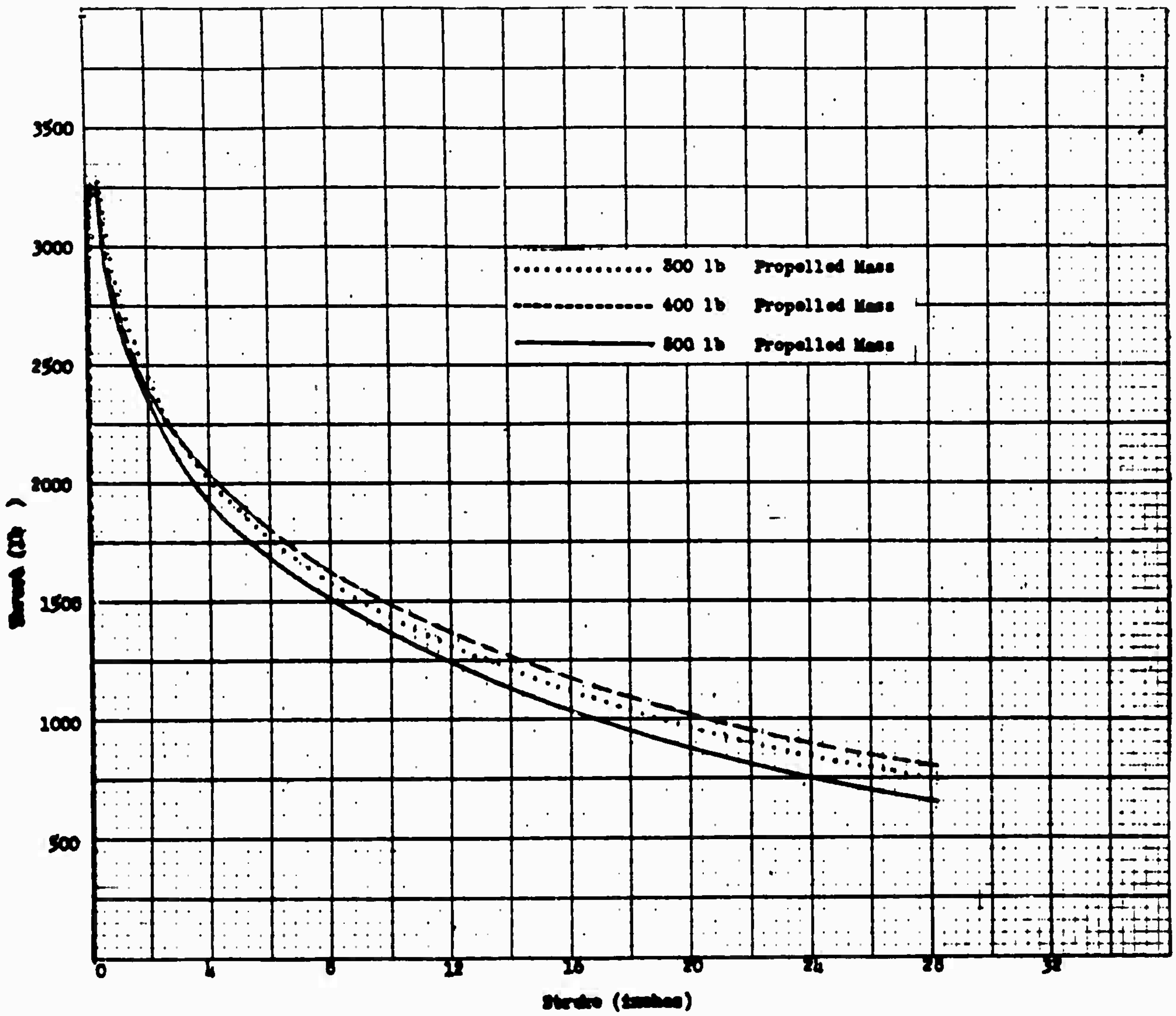

Figure 23. Representative thrust-stroke performance curves, T6 remover, propelling specific loads horizontally; firing temperature, -65° F

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R-1347

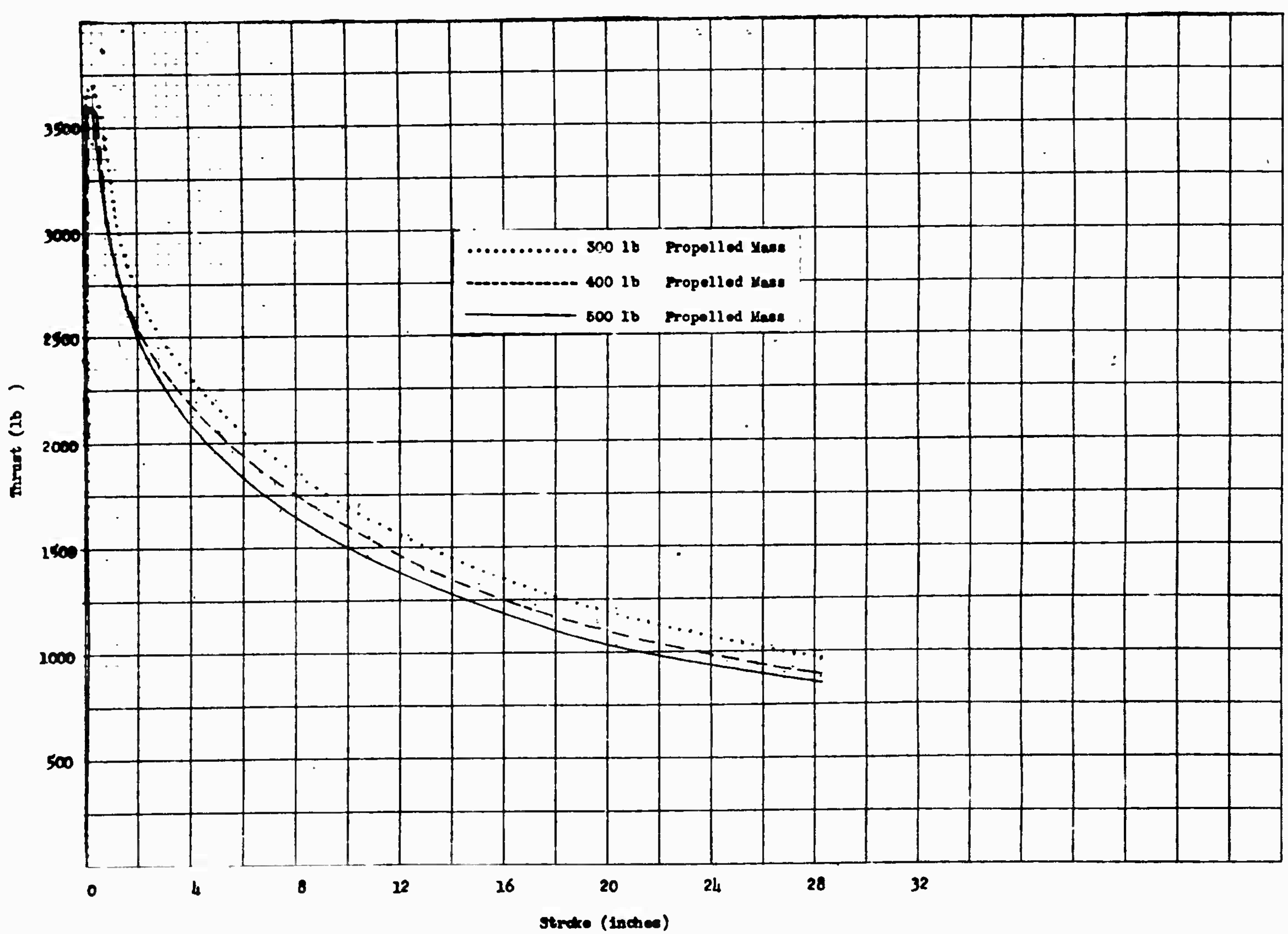

Figure 24. Representative thrust-stroke performance curves, T6 remover, propelling specific loads horizontally; firing temperature, 160° F

Neg. #30868
R-1347

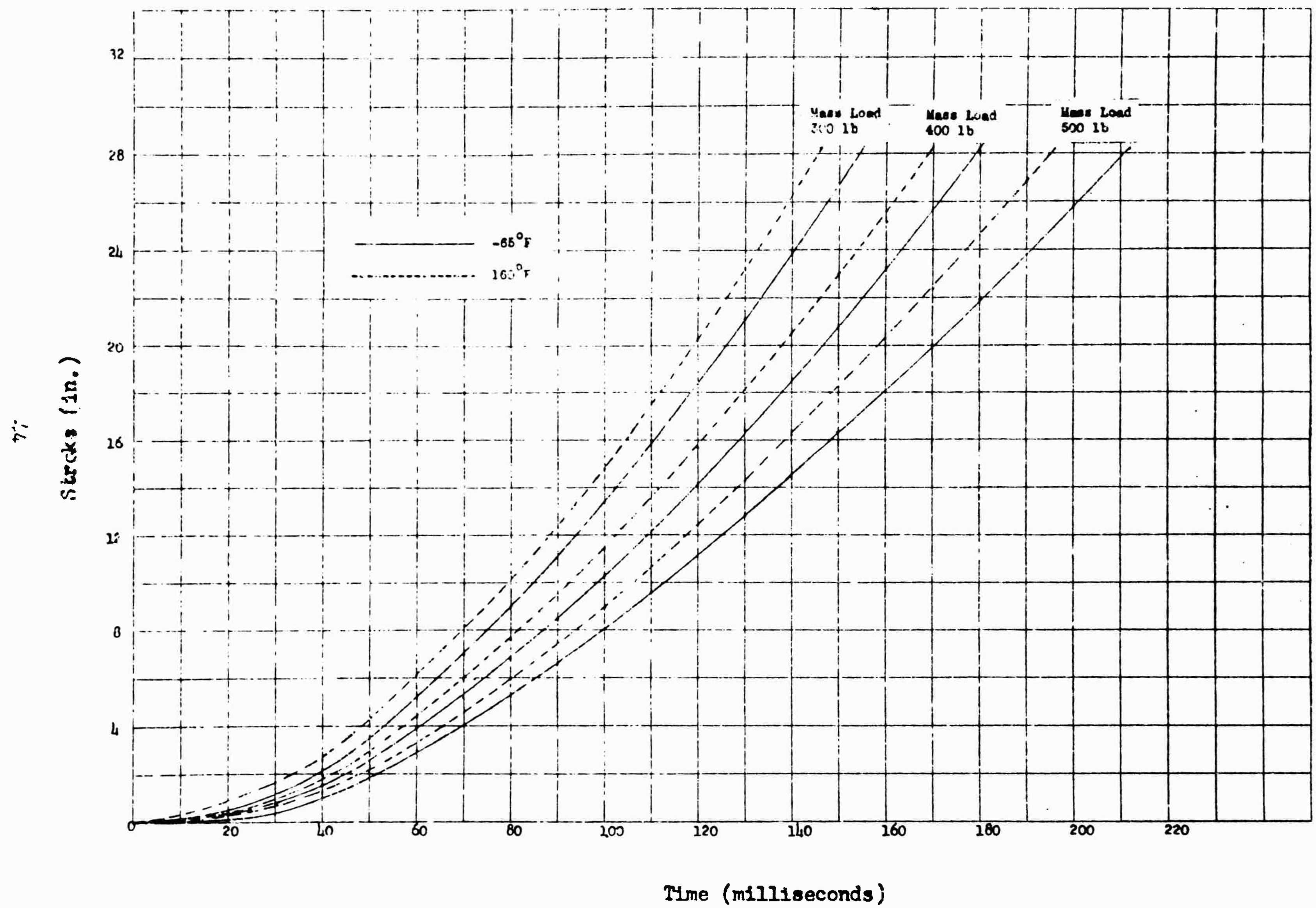

Figure 25. Representative stroke-time performance curves, T6 remover, propelling specific loads horizontally

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R-1347

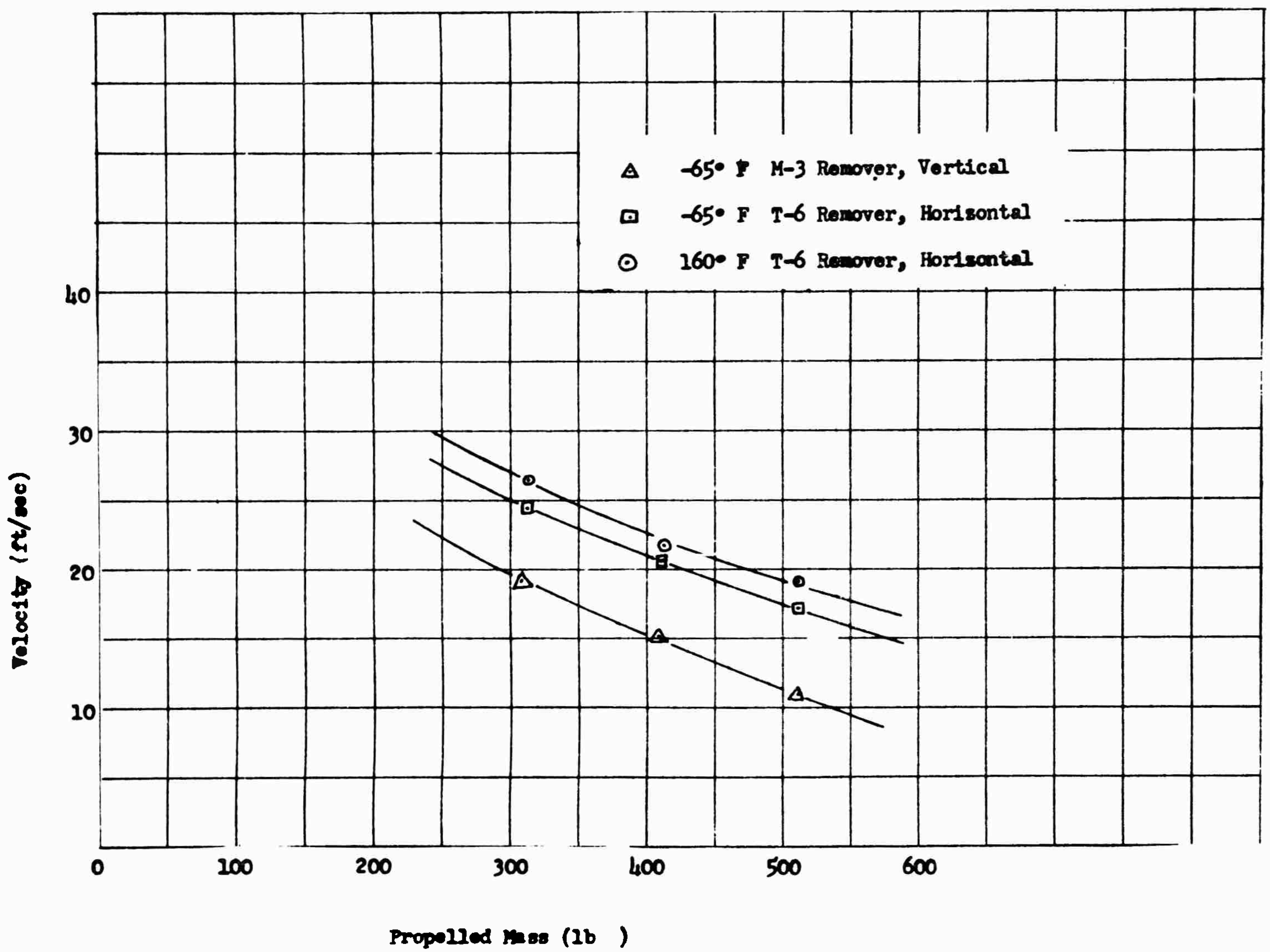

Figure 26. Average velocity vs propelled mass performance curves for T6 and M3 removers

The time required to complete stroke is significantly increased by an increase in the weight propelled and by the addition of a retarding acceleration field, as in test firings in the vertical position (Table VII).

Table VII. Stroke-Time Data for M3 (T6) Remover

No. of Rounds	Position	Propelled Weight (lb)	Temp (°F)	Time to Complete Stroke (sec) Max	Min	Avg
5	Horizontal	300	-65	0.154	0.150	0.152
5	"	300	160	0.146	0.144	0.145
5	"	400	-65	0.182	0.178	0.180
5	"	400	160	0.178	0.170	0.174
5	"	500	-65	0.214	0.200	0.206
5	"	500	160	0.200	0.194	0.197
9	Vertical	300	-65	0.181	0.170	0.173
10	"	400	-65	0.213	0.208	0.211
10	"	500	-65	0.265	0.248	0.257

An increase in stroke time results in increased dissipation of energy which is lost in raising the wall temperature of the remover. Consequently, less energy is available for the production of mechanical energy. The initial wall temperature (firing temperature) significantly affects the production of mechanical energy because less heat is lost to the walls of the remover when they are initially at a higher temperature.

Phase C: Performance Evaluation of M5 (T4E1) Thruster

The object of this phase of the evaluation program was to determine whether the M5 thruster would provide sufficient force to overcome the resistance of the canopy latch system (Figure 3). In these tests the initial restraining force of the canopy latch system was approximated with a steel shear pin placed at zero stroke position. The moving mass was 20 lb. The performance data are summarized in Table VIII.

Table VIII. Performance Data for M5 Thruster

No. of Rounds	Temp (°F)	Thrust (lb) At Pin Shear Max	Min	Avg	Peak Max	Min	Avg	Final Max	Min	Avg
5	-65	1500	1150	1350	1930	1560	1710	1470	1170	1300
5	160	1720	1270	1490	2550	2250	2410	2060	1930	1990

Curves prepared from the records of pressure, time, and piston stroke for each test round are presented in Figures 27 to 30, inclusive. Data on initial, peak, and final thrust; time to start of motion; peak thrust; and total stroke for each test firing are given in the Appendix.

It is apparent from Figures 29 and 30 that the M5 thruster is capable of providing force which is more than sufficient for the movement of the canopy latch cylinder.

The performance of thruster type cartridge actuated devices varies with the mechanical system in which they are used. Such external conditions as inertial and resistive forces seriously affect both thrust-time and thrust-stroke performance. It must be understood that the data shown in Figures 27 to 30, inclusive, and in the Appendix, represent performance of the thruster only under the test conditions for this program. The performance of the M5 thruster under other test conditions is discussed elsewhere.*

Phase D: Evaluation of Operational Reliability of Remover, M3, under Tension Loading Conditions

A minimum of approximately 800 psi acting on the firing pin is required for shear of the firing pin shear pin in the present design of the M3 remover, under conditions of static loading. It is believed that pressure of this magnitude will provide the firing pin with sufficient energy to unlock the remover and fire the primer. Therefore, successful completion of pin shear under these conditions is tantamount to successful initiation of the remover. In the tests conducted for this phase of the evaluation program, careful study was given to the effects of tension loading on the pressure at which pin shear was completed. A significant correlation between pressure at pin shear and tension loading, it was believed, would indicate whether initiation failure could be expected with more frequency when initiation is attempted while the remover is under tension. In addition, these tests served as function tests. A record was obtained of test firings in which the remover was initiated while under tension.

The major portion of tests for this phase was conducted with the remover initiated by an M3 initiator through 2.5 ft of flexible hose. These tests were conducted with tension loads up to 9500 lb. In all test firings the remover was successfully initiated. However, in two test firings with tensions of 9000 and 9500 lb, respectively, the remover failed structurally. The failures were due to rupture at the base caused by excessive bending stress in the base cap. These are not considered initiation failures.

*References Nos. 1, 12, 13, and page 13 of this report.

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R-1347

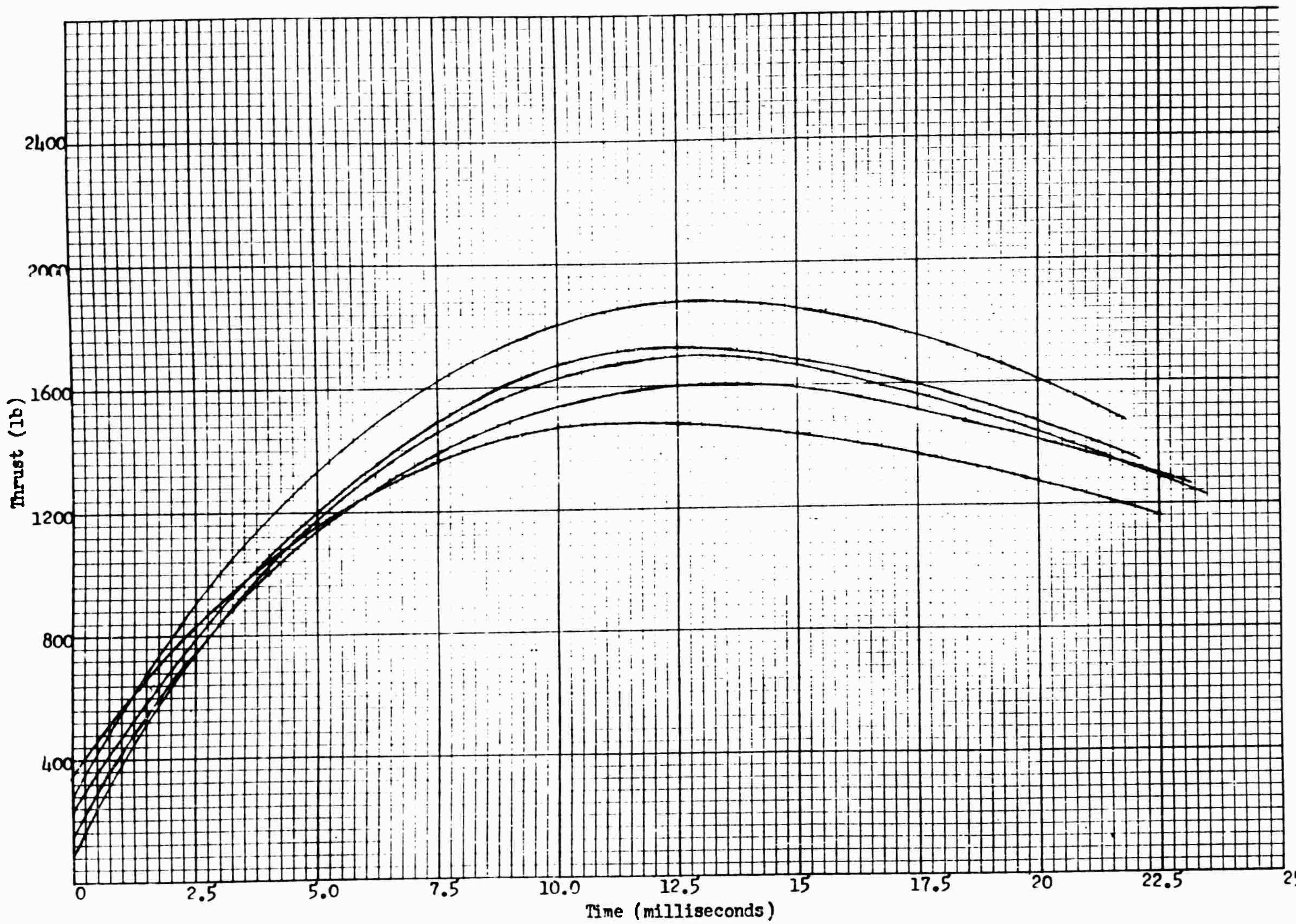

Figure 27. Thrust-time performance curves, M5A1 thruster, propelling 20-lb load; 1000-lb shear pin at zero stroke position; firing temperature, -65° F

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R-1347

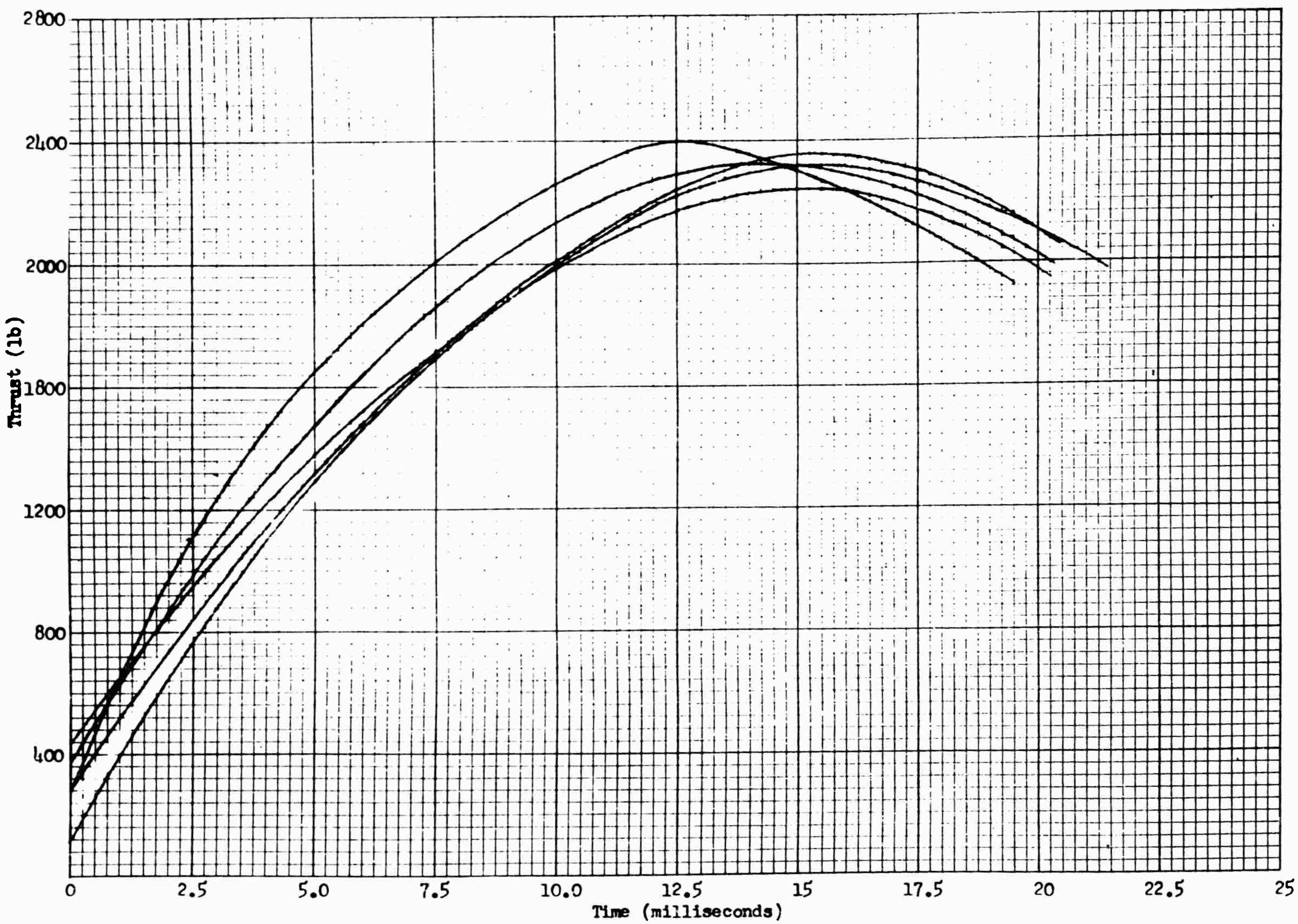

Figure 28. Thrust-time performance curves, M5A1 thruster, propelling 20-lb load; 1000-lb shear pin at zero stroke position; firing temperature, 160° F

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R-1347

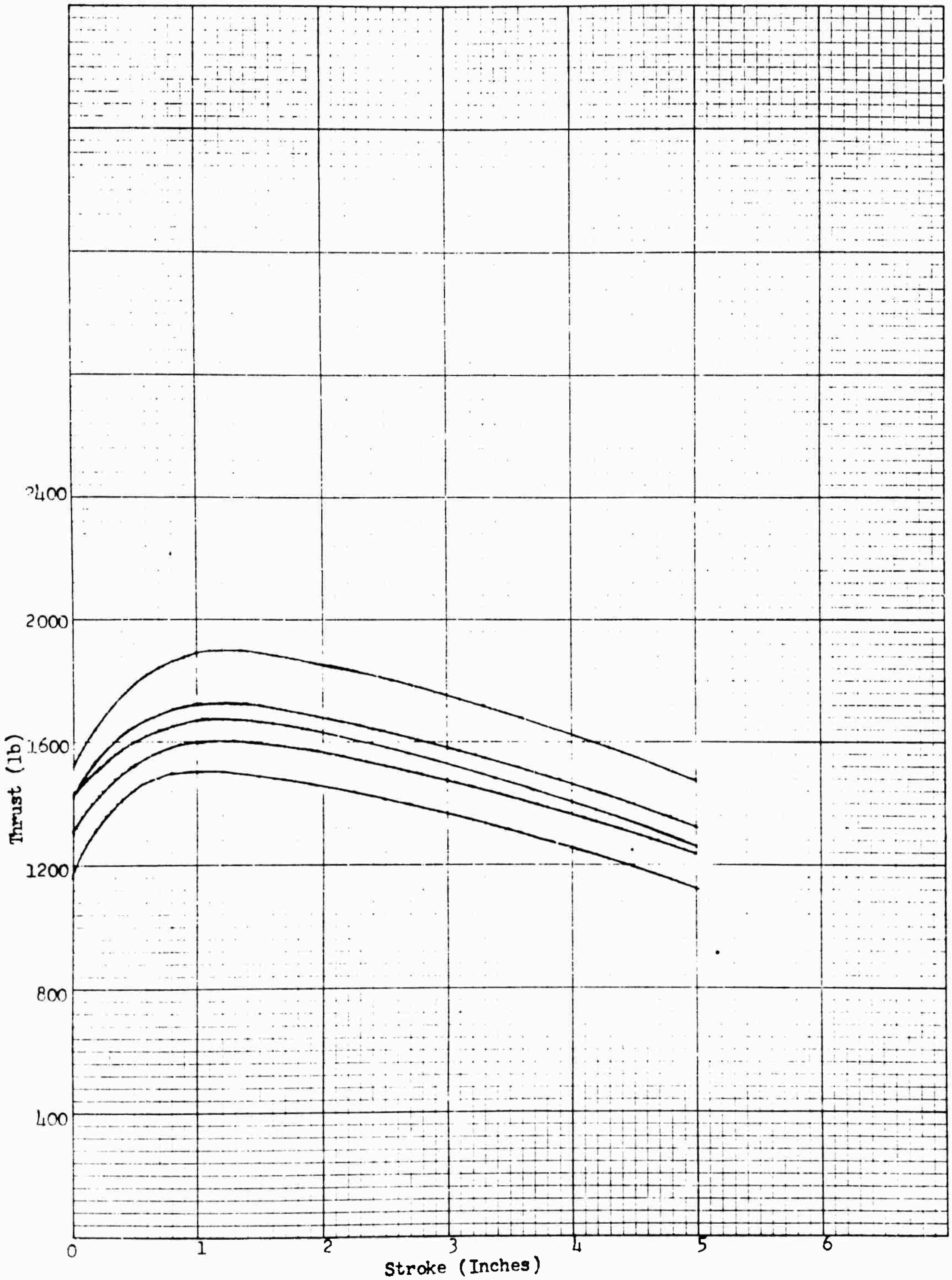

Figure 29. Thrust-stroke performance curves, M5A1 thruster, propelling 20-lb load; 1000-lb shear pin at zero stroke position; firing temperature, -65° F

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R-1347

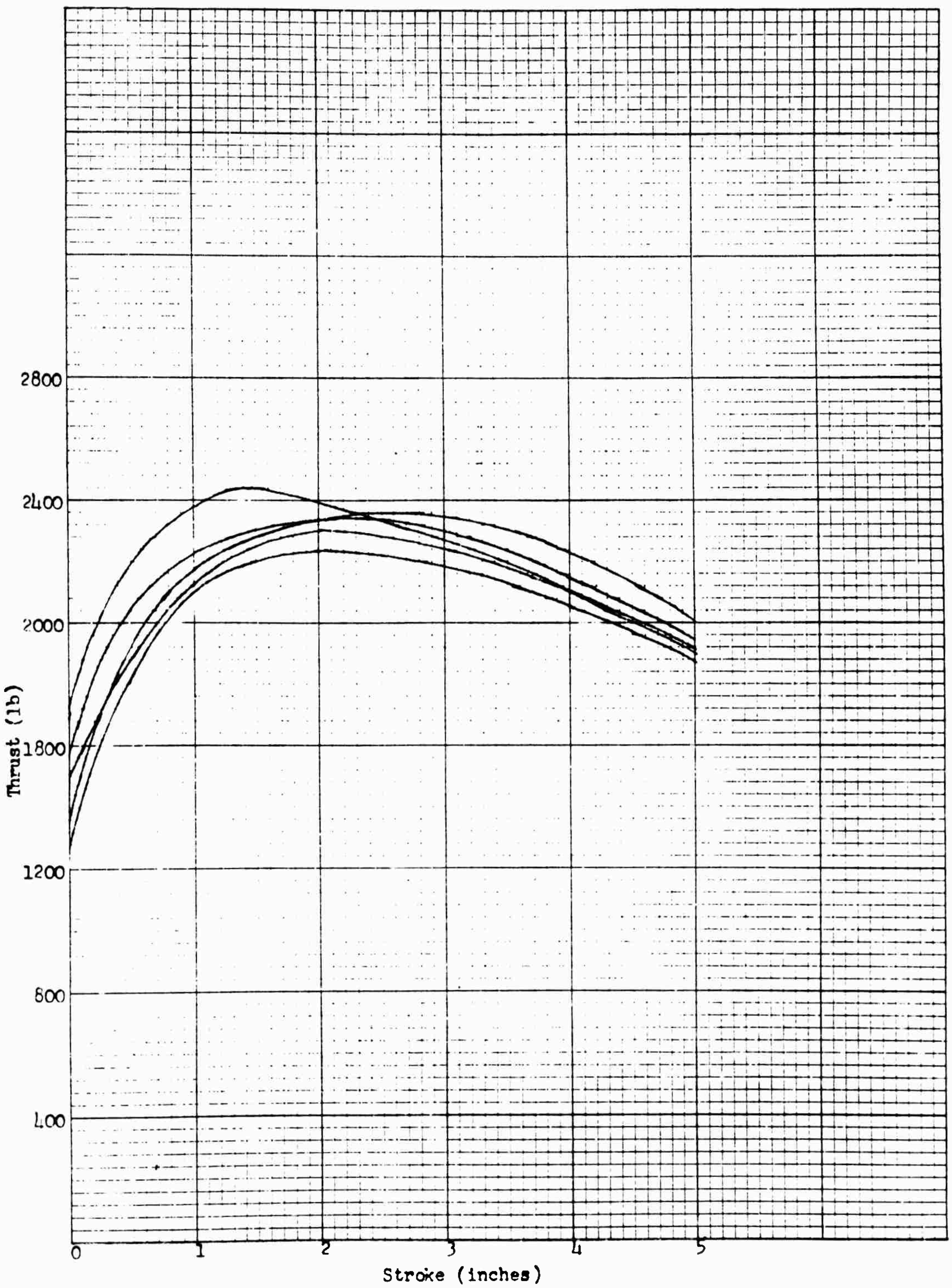

Figure 30. Thrust-stroke performance curves, M5A1 thruster, propelling 20-lb load; 1000-lb shear pin at zero stroke position; firing temperature, 160° F

An example of the pressure-time records obtained in these test firings is shown in Figure 31. Examination of the trace reveals two maxima. The lower (visible in Figure 31 as a break) is the pressure at completion of pin shear; the higher is referred to as the peak pressure.

The data on pressure at pin shear are summarized in Figure 32, which is a graph showing the values of pressure obtained plotted against the tension loading on the remover for each test firing. The average of all pressures obtained from the test firings in which 2.5 ft of flexible hose was used in the system, regardless of temperature, is also shown in Figure 32. It appears, on the basis of the data, that pressure at pin shear is independent of both firing temperature and tension loading. This conclusion applies only to test firings in which the remover was operated with an M3 initiator and 2.5 ft of flexible hose. On the basis of these data the relationship between tension loading and pressure at pin shear for other lengths of flexible hose cannot be predicted.

A small number of test firings was conducted under other test conditions. In one program, 9 test firings were conducted with the system at -65° F and the remover under 9000-lb tension. The object of these tests was a preliminary investigation into the effect of using greater lengths of hose in the system when the remover is to be initiated under adverse conditions. One test firing each was conducted with hose lengths of 2.5, 6, and 9 ft, respectively. The performance was satisfactory. Another group of six test firings was conducted with 10 ft of flexible hose; in one test firing the remover failed to initiate. Examination of the shear pin for this test firing revealed that partial shear of the pin had taken place. While no firm conclusions can be drawn from these data, it appears that tension loads of sufficient magnitude can affect the operational reliability of the M3 remover under certain circumstances.

Phase E: Final Performance Evaluation of Transmission System

The tests of this phase of the evaluation program were conducted in order to provide experimental evidence that the cartridge actuated devices (T4E1 thruster and M5 initiator) could be reliably operated when used as part of the proposed escape system. In this evaluation, function testing was combined with a quantitative study of pressure delivered to the firing blocks of the devices during operation. The systems were conditioned at -65° F prior to firing. The results of test firings for the four subsystems are summarized in Table IX.

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R-1347

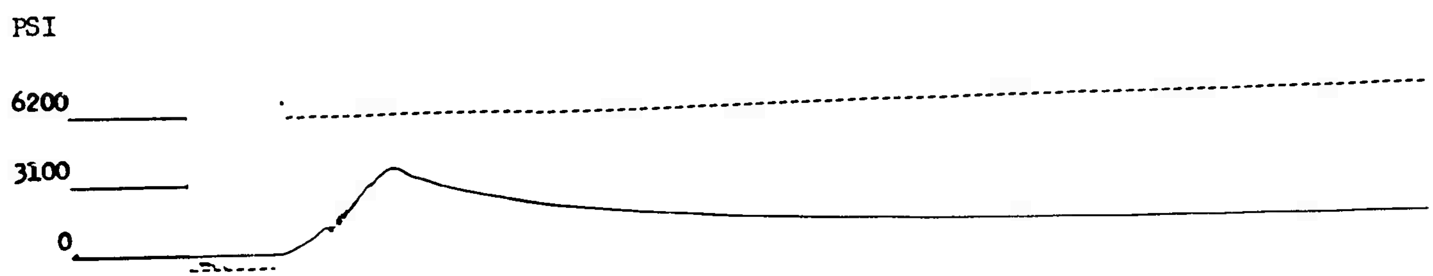

Figure 31. Oscillo-record of pressure in block of M3 remover fired under tension. Breaks in horizontal line represent 0.002-second time intervals

Neg. #30874
R-1347

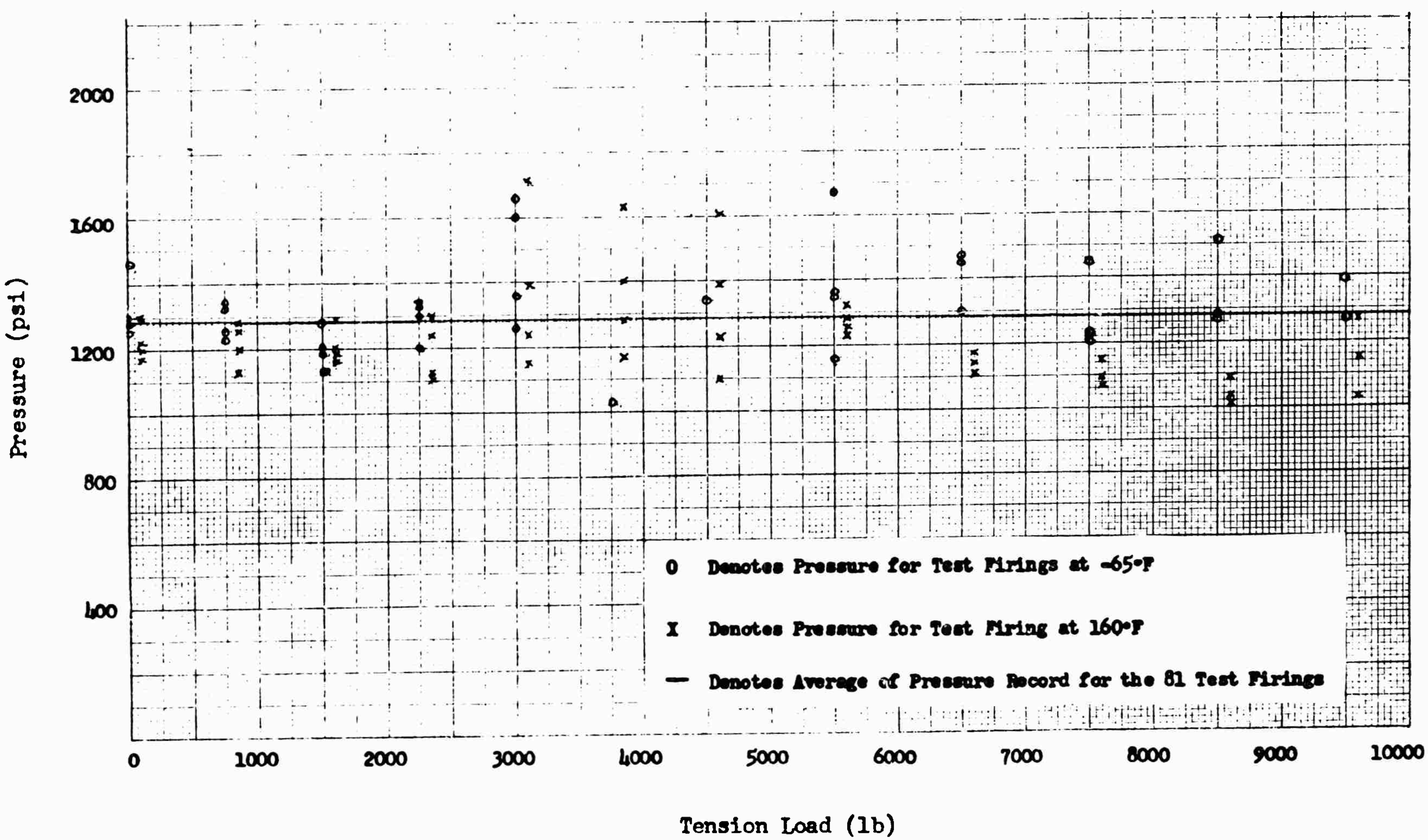

Figure 32. Pressure at pin shear vs tension loading, M3 remover

Table IX. Performance Data on Subsystems

Subsystem	Pressure (psi) Peak Max	Peak Min	Peak Avg	At Pin Shear Max	At Pin Shear Min	At Pin Shear Avg
Ground release	1410	1020	1220	450	180	350
Navigator's control	1510	850*	1430	390	220	320
Pilot's control	1230	1050	1140	400	290	340
Booster initiator operation	1630	1430	1500	490	180	300

Note: In all test firings the cartridge actuated device was initiated successfully.

*Check valve opened; value not included in average.

On the basis of the above data it may be presumed that the performance of the initiating systems will be satisfactory and that the various devices of the escape system can be initiated with a large margin of safety so far as initiating pressure is concerned.

CONCLUSIONS

On the basis of the work described in this report it is concluded that

1. The proposed canopy jettison system (Figure 1) is ballistically satisfactory.

2. The M3 remover will be reliably initiated while in tension not in excess of 9000 lb (the structural strength of the remover) by an M3 initiator through 2 1/2 ft of aircraft flexible hose (AN6271-4).

3. Peak thrust of the M3 remover is relatively insensitive to any increase in inertial load beyond 300 lb.

RECOMMENDATION

It is recommended that an investigation be conducted to determine whether circumstances exist under which the firing pin shear pin in a gas-operated cartridge actuated device such as the M3 remover can be sheared without firing the cartridge.

APPENDIX

PERFORMANCE EVALUATION

<u>Phase A: Transmission System - Preliminary Tests</u>

1. Ground Release Control

a. System: M3 initiator through 9 in. stainless steel tubing, bulkhead union (AN832-4), 50 in. flexible hose (AN6271-4), check valve (AN6249-4), cross (AN937-4) with exposed sides plugged, union (AN815-4), 12 in. flexible hose (AN6271-4), union (AN815-4), to T4E1 thruster, with M38 cartridge (primed only).

Round No.	Temp (°F)	System Function
1	-65	Satisfactory
2	-65	"
3	-65	"
4	-65	"
5	-65	"

b. System: Same as (a), but with thruster replaced by pressure block

Round No.	Temp (°F)	Peak Pressure (psi)
1520	-65	1500
1521	-65	1480
1522	-65	1560
1523	-65	1430
1524	-65	1530

2. Pilot's Control

a. System: M3 initiator through 10 in. flexible hose (AN6271-4), Wiggins disconnect, 72 in. flexible hose (AN6271-4), 45° elbow (AN837-4), 14 in. flexible hose (AN6271-4), check valve (AN6249-4), cross (AN937-4) with exposed sides plugged, union (AN815-4), 12 in. flexible hose (AN6271-4), union (AN815-4), to T4E1 thruster, with M38 cartridge (primed only).

Round No.	Temp (°F)	System Function
1	-65	Satisfactory
2	-65	"
3	-65	"
4	-65	"
5	-65	"

b. System: Same as (a), but with thruster replaced by pressure block

Round No.	Temp (°F)	Peak Pressure (psi)
1515	-65	1050
1516	-65	1220
1517	-65	1130
1518	-65	1360
1519	-65	1210

3. Remover Operation

a. System: M3 initiator through 23.5 in. flexible hose (AN6271-4), Wiggins disconnect, 11.5 in. flexible hose (AN6271-4), bulkhead union (AN832-4), 73 in. flexible hose (AN6271-4), union (AN815-4), 18 in. flexible hose (AN6271-4), 45° elbow (AN837-4), 12.5 in. flexible hose (AN6271-4), nipple (AN816-4), to M3 remover with M31A1 cartridge (primed only); firing block instrumented for recording pressure.

Round No.	Peak Pressure (psi)	System Function
1530	No record	Remover failed to initiate.
1531	420	Ditto
1532	710	Ditto
1533	950	Ditto
1534	870	Ditto
1538	790	Ditto
1539	510	Ditto
1540	750	Ditto

b. System conditioned at 70° F

Round No.	Pressure (psi) Peak	At Pin Shear	System Function
1535	1020	1020	Remover initiated
1536	1060	1060	Ditto
1537	1100	-	Remover failed to initiate*

*Evidence of partial pin shear

Phase B: Remover, M3

Propellant charge: 23 gm RAD 5316
Igniter: 25 gr Al black powder
Cartridge: M31A1

Round No.	Temp (°F)	Peak Thrust (lb)	Time to Peak Thrust (sec)	Velocity (f/s)	Mechanical Energy Developed* (ft-lb)	Total Stroke Time (sec)
Remover fired on horizontal test track						
Propelled mass: 312 lb						
111	-65	3340	0.022	24.4	2890	0.152
112	-65	3390	0.022	25.5	3140	0.150
113	-65	3270	0.022	24.7	2960	0.152
114	-65	3040	0.020	24.2	2830	0.154
115	-65	3160	0.020	24.9	3020	0.154
116	-65	3700	0.014	26.2	3330	0.146
117	-65	3840	0.014	27.0	3540	0.144
118	-65	3780	0.016	26.9	3510	0.144
119	-65	3750	0.014	26.6	3430	0.146
120	-65	3760	0.016	26.0	3270	0.146
Propelled mass: 412 lb						
121	-65	3240	0.022	20.3	2630	0.180
122	-65	3430	0.020	20.8	2770	0.178
123	-65	3570	0.022	21.4	2930	0.178
124	-65	3240	0.018	20.6	2720	0.182
125	-65	3210	0.024	20.7	2740	0.180
126	160	3650	0.016	21.9	3060	0.174
127	160	3790	0.014	21.6	2990	0.178
128	160	3720	0.016	22.2	3140	0.176
129	160	3610	0.014	22.1	3120	0.170
130	160	3720	0.018	21.3	2910	0.174

*Mechanical energy developed equals the sum of potential and kinetic energy of mass load at tube separation.

Round No.	Temp (°F)	Peak Thrust (lb)	Time to Peak Thrust (sec)	Velocity (f/s)	Mechanical Energy Developed* (ft-lb)	Total Stroke Time (sec)
Propelled mass: 512 lb						
131	-65	3250	0.024	17.2	2360	0.214
132	-65	3180	0.022	18.2	2630	0.210
133	-65	3040	0.026	17.1	2370	0.202
134	-65	3040	0.020	18.2	2700	0.200
135	-65	3250	0.024	18.0	2600	0.204
136	160	3670	0.018	19.0	2880	0.198
137	160	3710	0.016	19.3	2920	0.196
138	160	3670	0.018	19.2	2940	0.196
139	160	3638	0.018	19.1	2920	0.194
140	160	3460	0.016	18.7	2770	0.200
Remover fired on vertical test track (upward)						
Propelled mass: 309 lb						
16-1	-65	3320	0.026	20.3	2660	0.174
16-2	-65	3100	0.022	19.6	2520	0.170
16-3	-65	2980	0.023	19.4	2480	0.171
16-4	-65	2830	0.021	19.4	2480	0.171
16-5	-65	3010	0.022	19.5	2500	0.170
16-6	-65	3010	0.023	19.6	2520	0.171
16-7	-65	- - - - - - - - No	record - - - -	- - - -	- - - -	- - -
16-8	-65	2980	0.023	19.8	2560	0.181
16-9	-65	3040	0.023	19.6	2520	0.173
16-10	-65	3010	0.023	18.9	2390	0.173
Propelled mass: 409 lb						
16-11	-65	3010	0.024	15.2	2360	0.209
16-12	-65	3040	0.024	15.0	2320	0.209
16-13	-65	2930	0.023	15.4	2400	0.208
16-14	-65	2870	0.022	14.7	2260	0.212
16-15	-65	2960	0.023	14.9	2300	0.213
16-16	-65	3070	0.023	15.2	2360	0.211
16-17	-65	3020	0.023	15.2	2360	0.213
16-19	-65	2980	0.025	15.7	2460	0.210
16-20	-65	3010	0.025	14.9	2300	0.213
16-21	-65	2950	0.025	15.2	2360	0.210

*Mechanical energy developed equals the sum of potential and kinetic energy of mass load at tube separation.

Round No.	Temp (°F)	Peak Thrust (lb)	Time to Peak Thrust (sec)	Velocity (f/s)	Mechanical Energy Developed* (ft-lb)	Total Stroke Time (sec)
Propelled mass: 509 lb						
16-22	-65	3100	0.025	11.5	2150	0.255
16-23	-65	2960	0.025	11.4	2130	0.255
16-24	-65	2990	0.025	10.8	2020	0.260
16-25	-65	3070	0.025	12.1	2260	0.248
16-26	-65	3090	0.025	11.4	2130	0.253
16-27	-65	3010	0.026	11.0	2060	0.261
16-28	-65	2820	0.025	10.2	1920	0.265
16-29	-65	2950	0.028	11.5	2150	0.258
16-30	-65	2980	0.025	11.4	2130	0.255
16-31	-65	3010	0.025	10.8	2020	0.263

*Mechanical energy developed equals the sum of potential and kinetic energy of mass load at tube separation.

Phase C: M5 (T4E1) Thruster

Propellant charge: 2.8 gm RAD 5280
Igniter: 1.0 gm A4 black powder
Cartridge: M38

Thruster fired on horizontal track; shear pin (shear value, 1000 lb) placed at zero stroke position. Propelled mass: 20 lb

Round No.	Temp (°F)	Thrust (lb)			Time (sec)		
		Pin Shear	Peak	Final	Pin Shear	Peak	Total Stroke
9	-65	1150	1560	1170	0.005	0.012	0.023
10	-65	1430	1740	1340	0.007	0.013	0.022
11	-65	1380	1930	1470	0.006	0.014	0.024
12	-65	1290	1620	1290	0.006	0.014	0.021
13	-65	1500	1680	1250	0.008	0.013	0.023
2	160	1720	2430	1930	0.005	0.014	0.018
3	160	1510	2550	2060	0.006	0.016	0.020
16	160	1270	2250	1950	0.004	0.014	0.020
17	160	1570	2480	2000	0.004	0.014	0.020
18	160	1360	2360	2020	0.005	0.015	0.021

Phase D: Reliability of M3 Remover when Operated under Tension Loading

System: M3 initiator through flexible hose and special 90° elbow with pressure station to M3 remover with M31A1 cartridge (primed only)

Round No.	Temp (°F)	Hose Length (ft)	Tension Load (lb)	Pressure (psi) Shear	Pressure (psi) Peak	System Function
1	70	2.5	650	1040	4740	Satisfactory
2	70	2.5	400	1200	5210	"
3	-65	2.5	0	1460	4350	"
4	-65	2.5	0	1260	4620	"
5	-65	2.5	0	1300	4380	"
6	-65	2.5	0	1280	4430	"
7	160	2.5	0	1200	3570	"
8	160	2.5	0	1170	3330	"
9	160	2.5	0	1300	4380	"
10	160	2.5	0	1220	3780	"
11	-65	2.5	750	1330	4040	"
12	-65	2.5	750	1230	4220	"
13	-65	2.5	750	1260	4010	"
14	-65	2.5	750	1330	4010	"
15	160	2.5	750	1280	3330	"
16	160	2.5	750	1260	3470	"
17	160	2.5	750	1130	3740	"
18	160	2.5	750	1200	4180	"
19	-65	2.5	1500	1200	3100	"
20	-65	2.5	1500	1280	4100	"
21	-65	2.5	1500	1130	4020	"
22	-65	2.5	1500	1200	3980	"
23	160	2.5	1500	1190	4180	"
24	160	2.5	1500	1170	4030	"
25	160	2.5	1500	1290	3930	"
26	160	2.5	1500	1200	4030	"
27	-65	2.5	2250	1330	3820	"
28	-65	2.5	2250	1330	3540	"
29	-65	2.5	2250	1300	3680	"
30	-65	2.5	2250	1200	3700	"
31	160	2.5	2250	1120	3670	"
32	160	2.5	2250	1240	4400	"
33	160	2.5	2250	1120	4310	"
34	160	2.5	2250	1300	3310	"

Round No.	Temp (°F)	Hose Length (ft)	Tension Load (lb)	Pressure (psi) Shear	Peak	System Function
35	-65	2.5	3000	1360	3750	Satisfactory
36	-65	2.5	3000	1600	3780	"
37	-65	2.5	3000	1260	3410	"
38	-65	2.5	3000	1660	3710	"
39	160	2.5	3000	1710	4330	"
40	160	2.5	3000	1390	4340	"
41	160	2.5	3000	1240	3880	"
42*	160	2.5	3000	1150	3860	"
43	160	2.5	3750	1170	4320	"
44	160	2.5	3750	1630	4550	"
45	160	2.5	3750	1400	4530	"
46	160	2.5	3750	1280	3980	"
47	-65	2.5	3750	No record		"
48	-65	2.5	3750	No record		"
49	-65	2.5	3750	No record		"
50	-65	2.5	3750	1030	2940	"
51	160	2.5	4500	1610	3890	"
52	160	2.5	4500	1100	4290	"
53	160	2.5	4500	1390	3930	"
54	160	2.5	4500	1230	4360	"
55	-65	2.5	4500	No record		"
56	-65	2.5	4500	No record		"
57	-65	2.5	4500	1340	3060	"
58	-65	2.5	4500	No record		"
59	160	2.5	5500	1280	3710	"
60	160	2.5	5500	1250	4770	"
61	160	2.5	5500	1320	4160	"
62	160	2.5	5500	1260	4160	"
63	-65	2.5	5500	1670	3830	"
64	-65	2.5	5500	1350	3620	"
65	-65	2.5	5500	1160	3490	"
66	-65	2.5	5500	1350	3610	"
67	70	2.5	6500	1140	3460	"
68	-65	2.5	6500	1450	3800	"
69	-65	2.5	6500	1300	3490	"
70	-65	2.5	6500	1470	3770	"
71	-65	2.5	7500	1450	3330	"
72	-65	2.5	7500	1210	3270	"
73	-65	2.5	7500	1210	3390	"

*On rounds 42 to 59, incl, the values of peak pressure recorded are subject to small error due to difficulty with piezo gage.

Round No.	Temp (°F)	Hose Length (ft)	Tension Load (lb)	Pressure (psi) Shear	Pressure (psi) Peak	System Function
74	-65	2.5	6500	1140	3910	Satisfactory
75	-65	2.5	6500	1110	3920	"
76	-65	2.5	6500	1170	3920	"
77	-65	2.5	7500	1150	3800	"
78	-65	2.5	7500	1090	3770	"
79	-65	2.5	7500	1090	3650	"
80	-65	2.5	8500	1030	4020	"
81	160	2.5	8500	1090	3700	"
82	160	2.5	8500	1030	4080	"
83	160	2.5	9500	1270	3580	"
84	160	2.5	9500	1150	3830	"
85	160	2.5	9500	1030	3640	"
86	-65	2.5	8500	1270	3080	"
87	-65	2.5	8500	1510	3570	"
88	-65	2.5	8500	1270	3440	"
89	-65	2.5	9500	1390	3320	"
90	-65	2.5	9500	End cap ruptured*		- - -
91	-65	2.5	9500	1270	3320	Satisfactory
92	-65	2.5	9000	End cap ruptured*		- - -
93	-65	6	9000	1350	2090	Satisfactory
94	-65	9	9000	1170	1600	"
95	-65	10	9000	1160	1510	"
96	-65	10	9000	**	1730	- - -
97	-65	10	9000	1190	1410	Satisfactory
98	-65	10	9000	1320	1600	"
99	-65	10	9000	1260	1440	"
100	-65	10	9000	1350	1630	"

*Failure due to excessive bending stress in hose trunnion

**Shear pin failed to shear

Phase E: Final System Evaluation Tests

1. Ground Release

System: M3 initiator through 9 in. stainless steel tubing, bulkhead union (AN832-4), 50 in. flexible hose (AN6271-4), check valve (AN6249-4), cross (AN937-4) with check valves, union (AN865-4), 12 in. flexible hose (AN6271-4), 90° elbow with pressure station, to T4E1 (M5) thruster, with M38 cartridge (primed only).

Round No.	Temp (°F)	Pressure (psi) Peak	Pressure (psi) At Pin Shear	System Function
1-1	-65	1370	450	Satisfactory
1-2	-65	1360	410	"
1-3	-65	1020	470	"
1-4	-65	1410	410	"
1-5	-65	1250	180	"
1-6	-65	1130	420	"
1-7	-65	1150	360	"
1-8	-65	1040	360	"
1-9	-65	1260	310	"
1-10	-65	1150	340	"

2. Navigator's Control

System: M3 initiator through 10 in. flexible hose (AN6271-4), Wiggins disconnect, 38 in. flexible hose (AN6271-4), 45° elbow (AN837-4), 27 in. flexible hose (AN6271-4), check valve (AN6249-4), cross (AN937-4) with check valves, union (AN815-4), 12 in. flexible hose (AN6271-4), 90° elbow with pressure station, to T4E1 (M5) thruster with the M38 cartridge (primed only).

Round No.	Temp (°F)	Pressure (psi) Peak	Pressure (psi) At Pin Shear	System Function
2-1	-65	1510	340	Satisfactory
2-2	-65	1360	370	"
2-3	-65	1420	220	"
2-4	-65	850*	260	"
2-5	-65	1330	220	"
2-6	-65	1420	390	"
2-7	-65	1480	390	"
2-8	-65	1420	330	"
2-9	-65	1470	390	"
2-10	-65	1410	310	"

*Check valve opened

3. Pilot's Control

System: M3 initiator through 10 in. flexible hose (AN6271-4), Wiggins disconnect, 72 in. flexible hose (AN6271-4), 45° elbow (AN837-4), 14 in. flexible hose (AN6271-4), check valve (AN6249-4), cross (AN937-4), with check valves, union (AN815-4), 12 in. flexible hose (AN6271-4), 90° elbow with pressure station, to T4E1 (M5) thruster with M38 cartridge (primed only).

Round No.	Temp (°F)	Pressure (psi) Peak	Pressure (psi) At Pin Shear	System Function
3-1	-65	1200	390	Satisfactory
3-2	-65	1230	370	"
3-3	-65	1120	340	"
3-4	-65	1230	400	"
3-5	-65	1090	310	"
3-6	-65	1170	290	"
3-7	-65	1090	340	"
3-8	-65	1100	330	"
3-9	-65	1130	330	"
3-10	-65	1050	290	"

4. Booster Initiator Operation

System: M3 initiator through 26 in. flexible hose (AN6271-4), Wiggins disconnect, 11 in. flexible hose (AN6271-4), bulkhead union (AN832-4), 73 in. flexible hose (AN6271-4), 90° elbow with pressure station to M5 initiator.

Round No.	Temp (°F)	Pressure (psi) Peak	Pressure (psi) At Pin Shear	System Function
4-1	-65	1480	*	Satisfactory
4-2	-65	1540	490	"
4-3	-65	1430	200	"
4-4	-65	1450	420	"
4-5	-65	1490	180	"
4-6	-65	1490	380	"
4-7	-65	1500	340	"
4-8	-65	1630	180	"
4-9	-65	1520	270	"
4-10	-65	1470	220	"

*Record defective

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